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ON THE ERRONEOUS RESULTS OF A STEREOSCOPIC COMBINATION OF PHOTOGRAPHS OF A COMET.*

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The stereoscope enables one to see objects in perspective by the combination of two photographs taken from a slightly different point of view. One way to accomplish this effect is to shift the position and direction of the camera by a proper amount between the taking of the two pictures. Essentially the same effect would be produced by the bodily displacement of the object with the camera stationary, provided all of the background were itself too distant for parallactic displacement. Both these methods would require that there were no relative change in the individual parts of the object in the interval between the two pictures. In practice, stereoscopic pictures are made by simultaneous exposures with twin lenses separated by a few inches. For celestial bodies, where our base line is too small to give any appreciable parallax, the last of the two methods is resorted to. In the case of the Moon the perspective is obtained by the aid of libration; and as the phase has to be exactly the same, a very long interval is required. In the case of a bright asteroid an interval of an hour, or of a proper motion star of several years, will produce the required effect. The short interval is also applicable to a comet, and beautiful and startling effects are produced by this means in the case of a comet with a tail. Few bright comets, however, are above the horizon long enough to permit the two photographs to be made for this purpose. On account of its high north declination, and its consequent visibility through all or nearly all the night, comet *c* 1908 (Morehouse) was specially suited for stereoscopic photographs, and the material acquired for this purpose is abundant. The combinations of proper sets of these pictures show the comet in beauti-

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ful relief suspended alone in space, as we know it is in reality, with the various parts of the tail in individual perspective. There is a wonderful effect of reality in these pictures, and the filmy, breath-like character of the comet is shown as no single picture can even hope to show it. These photographs are marvellously instructive, and one is tempted to deduce certain "facts" from the appearance which are probably entirely erroneous.

This is such a serious matter, and one so fascinatingly delusive, that I have thought it worth while to draw attention to the chances for serious errors that are inherent in the very success of the experiment in the case of a comet.

I have combined a number of photographs of the present comet in which the motion in an hour or so, between the exposures, permits stereoscopic effect. One of the most remarkable of these combinations is that of October 15, 1908. On this date there was a sudden twist or break in the tail, which formed irregular cloud-like masses that moved out from the comet along the general direction of the tail. In the stereoscope these two pictures produce an exquisite object suspended in front of the stars. Apparently it is easy to see which are the farther and which the nearer parts of the comet. The south end of the long irregular mass at an angle to the tail is the nearer. From this the tail has a twisted or corkscrew form, the nearer and farther convolutions of which are at once evident. The straight stem-like tail emanating from the head passes behind this mass. On each side of the head is a small stream shot out at a considerable angle to the main tail. The south one of these apparently recedes from us at a large angle to the plane of the photograph. There are other peculiarities which will be apparent to any one viewing the picture, and which cannot be well described here.

But how much of this perspective is real? I believe that there is but little of it that can be true. In the first place, these masses were receding from the comet and changing their actual forms, and especially their position angles, so that a pseudo-stereoscopic effect would be produced, and what is really the nearer portion of the comet may appear to be a distant part. Some of the features where the details were not changing rapidly—as, for instance, the short tail from the south side of the head—would probably not be affected much by the outgoing particles, and a true stereoscopic effect would be produced. I have my doubts about much of the rest. It would be an interest-

ing problem to differentiate the effect of the individual motion of the masses from the parallactic effect, and thus be able to tell which are the nearer and which the distant parts of the comet.

In preparing this stereogram (October 15) much trouble was experienced in making the two pictures combine. The outward motion of the masses and their angular motion separate them too much for the best result. By reducing the scale of the images considerably this difficulty was overcome and a fairly good combination obtained. This trouble did not occur with the plate of November 16, because the details were of a different nature and easily reconcilable.

All of the pictures were made with the ten-inch Bruce lens. The times and durations for these are—

		G. M. T.		Duration.	
		h	m	h	m
1908 October 15	No. 1	12	58	1	22
	No. 2	14	31	1	30
1908 November 16	No. 1	12	14	1	5
	No. 2	13	46	1	50

In connection with this subject I would say that I never need the stereoscope to combine these pictures. By a certain control of my eyes, any stereoscopic picture is far more beautiful without the stereoscope, and I never use the instrument. The magnification of the image is somewhat less. Indeed, I have no trouble in perfectly combining thus the pictures of October 15, even when they are somewhat enlarged from the original. When one has this command over his eyes, he will never again use a stereoscope.

In the stereogram of November 16, the two narrow streams emanating from the head on the left hand (south) side are apparently ejected from the comet in a direction some 20° or 30° from the plane through the head, parallel to the plate, but away from us and beyond that plane. Those on the right or north seem to be ejected toward us, but this is rather uncertain. The entire comet has a beautiful filmy appearance, and some of the structures seem to be due to broad sheets of matter. I have compared Nos. 1 and 3 of this date, but the changes have been too large to secure good adjustment.

The comparisons of November 18 do not produce such a striking and beautiful effect, though it is very good.

While I believe that a good deal of the perspective on these stereograms is untrue, and that it does not accurately represent

the actual appearance of the comet at the time, it must not be understood that I would discourage the stereographic study of comets. I believe that much can be learned of the general structure of these bodies from such a study. We must simply be guarded as to the relative perspective of the various parts of the comet at that time, as resulting from a combination of the two photographs.

Though the appearance, in a stereograph, of any one comet may be partly false, there is certainly no other method that can show us how a comet really looks in space; and for this reason, if for no other, it will, I believe, in a truthful manner, help us to understand the features of comets in general.

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DYNAMICAL THEORY OF THE CAPTURE OF SATELLITES AND OF THE DIVISION OF NEBULAE UNDER THE SECULAR ACTION OF A RESISTING MEDIUM.* II

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VII. How the motions of the satellites become retrograde.

From the results indicated in *A. N.* 4308 and the foregoing considerations we see how all the planets and satellites have been captured—the former now revolving under the control of the Sun as superior or interior planets, the latter drawn down very close to the several planets, where alone stable motion is possible. The great preponderance of the Sun's control is due to its larger mass, but small closed surfaces exist about each planet, and in the case of Jupiter, Saturn, Uranus and Neptune, these surfaces are of considerable size.

If our system was once pervaded by a resisting medium, with an infinite number of particles and a lesser number of small bodies circulating everywhere in the spaces where the planets now move, just as the comets still do, then it is obvious that some of them would pass continually from the control of the Sun to that of these several planets; and under the influence of resistance they would sooner or later be captured.

Professor G. H. Darwin remarks in the passage above quoted:

* From *Astro. Nach.* 4341-42.

"If the neck of the hour-glass defining the curve of zero velocity be narrow, the body may move hundreds of times round one of the centers before its removal to the other." *And if the dynamical condition imposed by the resisting medium is introduced, he might well have added, a permanent capture will result. Thus Jove would acquire a real satellite; and when the major axis and eccentricity of the orbit had been reduced by the secular action of the resisting medium about the planet, the orbits of such bodies would be similar to those of the satellites now observed.*

It is especially important to point out that in passing from the Sun to Jove the orbits may be either retrograde or direct; for the body may enter the neck of the hour-glass in such a way as to cross over the line *SJ* before coming completely under Jove's control. In general, such a crossing satellite would probably be comparatively remote from the planet. But it should come nearer to the planet, where most of the satellites have direct motion in the denser revolving vortex of nebulosity about the central nucleus, the chances are that it would not survive, but in time be precipitated upon the planet, or disintegrated into dust when it came within Roche's limit.

Therefore it is not remarkable that only two known retrograde satellites have survived, while those with direct motion are more than ten times more numerous. Nor is it surprising that these retrograde satellites are on the outskirts of the systems of Jupiter and Saturn; for at this distance from these centers the resisting medium must have been of extreme tenuity. The fact that considerable eccentricities survive, 0.44 in the case of Jupiter VIII, and 0.22 in the case of Phoebe, both confirms this mode of capture, and indicates that the density of the medium at that great distance must have been quite small.

On the other hand, the greater roundness of the orbits of the other satellites nearer the planets, which revolved in a denser medium, naturally follows, as well as their direct revolution. It should not, however, be concluded that retrograde motion near these planets is wholly excluded; but merely that the chances of its surviving are very slight.

VIII. Theoretical and observed distances of satellites in the solar system.

In the theory of the closed surfaces about the planets it is shown that the superior limit of distance for a satellite which can just be retained by a planet is found by the condition that the neck of the hour-glass figure shall contract till the two

separate surfaces meet in a point between the Sun and planet, on the line SJ. This leads to a quintic equation, which, for small bodies such as those in our solar system, is shown to be capable of reduction to the simple form (Periodic Orbits, p. 109):

$$\rho = \frac{1}{(3\nu + 1)^{\frac{1}{3}} + \frac{1}{3}} \tag{15}$$

where ν is the mass of the Sun in terms of the planet's mass as unity, or the reciprocal of the planet's mass as ordinarily expressed.

The following table gives the principal data for the planets and satellites of the solar system, and shows the comparative magnitude of the closed surfaces about the several bodies, and what parts of these spaces are known to be occupied.

TABLE OF SATELLITE DISTANCES IN THE SOLAR SYSTEM.

Planet	Reciprocal of adopted mass (cf. *A. N.* 3923)	Satellite	Observed Distance in kilometers	Theoretical limit in kilometers	Theoretical limit in astron. units
Mercury	14868548	—	—	163086	0.001094
Venus	408134	—	—	1008152	0.006747
The Earth	328715	The Moon	384400	1497577	0.010013
Mars	3089967	Phobos	9377	1083118	0.0072419
		Deimos	23475		
Jupiter	1047.35	V	180936	51940750	0.347283
		I	421632		
		II	670859		
		III	1070067		
		IV	1882150		
		VI	11456800		
		VII	11891000		
		VIII	27475000		
Saturn	3500.00	Mimas	185475	69210900	0.4627540
		Enceladus	237942		
		Tethys	294555		
		Dione	377258		
		Rhea	526847		
		Titan	1221340		
		Hyperion	1479622		
		Iapetus	3559253		
		Phoebe	12886600		
Uranus	22780	Ariel	191312	69637300	0.465605
		Umbriel	266526		
		Titania	437174		
		Oberon	584626		
Neptune	19313	(nameless)	355518	115234000	0.770473

IX. On the future search for new satellites about the planets.

If we study the data in this table carefully, we shall perceive that the closed surfaces about some of the planets are almost entirely vacant or so little traversed by the known satellites that it is quite probable that other satellites may yet be discovered in these vacant spaces. In the case of Mercury the problem of searching for satellites is no doubt hopeless, because of the smallness of the closed space, and the difficulty of recognizing faint objects about a planet so near the Sun.

Venus holds out better prospects of possible discoveries; for the closed surface about this planet has more than twice the diameter of the orbit of our Moon, and is therefore ample for holding one or more satellites. As Venus admits of prolonged photographic search when at elongation, this method would be worthy of trial.

The possible satellites moving about the Earth, other than the Moon, hardly require discussion; but as the closed space beyond the Moon is very ample, it is by no means improbable that a small body may yet be found there.

We next turn to Mars, and there we find a large closed space, apparently unoccupied, except by the small satellites very near the planet, which were discovered by the late Professor Asaph Hall in 1877. If photography were applied to the outer region of this space, when Mars is very near the Earth, as it will be this year, it is quite possible, and even probable, that another faint body or two would be found to attend this interesting planet.

In the case of Jupiter, the search might be extended considerably further than it has yet been; for the outer half of the closed space is still unoccupied by any known satellite, and large vacant regions exist also among the known satellites, especially between the IVth and VIIIth. Of course, it does not follow that all the vacant spaces are really occupied; neither is the existence of pairs of satellites close together wholly excluded, as we see by the distances of the VIth and VIIth satellites recently discovered by Perrine at the Lick Observatory. (Fig. 4).

The sphere of Saturn's possible domain for satellites is even larger than that of Jupiter, and is still relatively less occupied. New satellites are therefore most likely to be found in this grand system.

In the case of Uranus there is a large domain apparently vacant on the outside, all the known satellites being concen-

trate quite near the center. Is it not likely that other bodies will be found at greater distance?

Similar remarks apply to Neptune, which, owing to its great distance from the Sun, has the largest closed space of any of the planets. As enough nebulosity was gathered into these remote planets to give them considerable masses, and the nebular resistance was great enough to round up their orbits, it seems

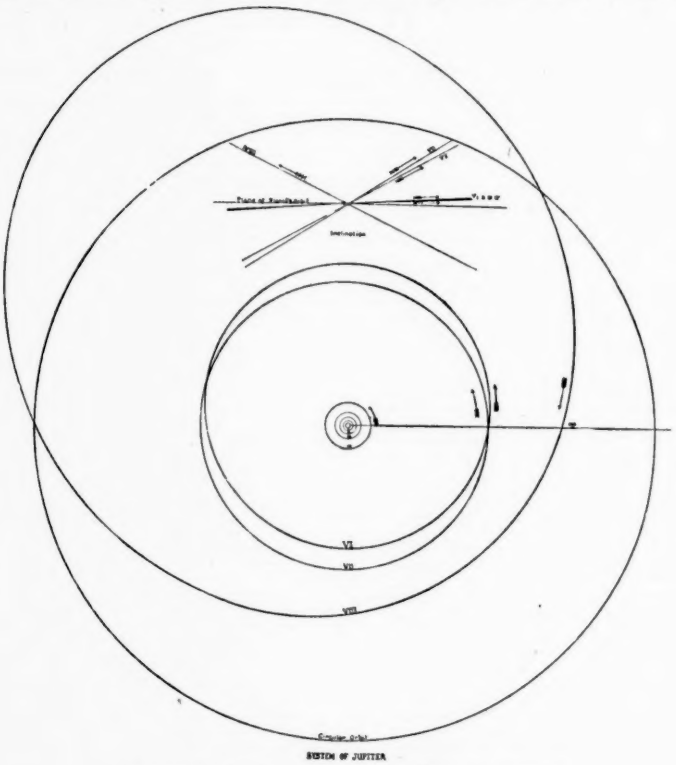

FIGURE 4.—DIAGRAM OF THE SYSTEM OF JUPITER.

almost certain that they must have numerous satellites still undiscovered. Photography can be applied here with full effect, and persistent searches with the longest exposures and most powerful photographic telescopes is to be recommended.

X. DYNAMICAL THEORY OF THE DIVISION OF NEBULAE.

That there is in nature a general dynamical process by which condensing nebulae divide into fairly equal parts and form

double stars has long been held by the present writer (*cf.* Inaugural Dissertion, Berlin, 1892). This conclusion was first reached from the study of the brightness and probable masses of binary stars about May, 1886; and in the latter part of 1889 the double nebulae depicted by Sir John Herschel in the Philosophical Transactions of the Royal Society for 1883, were connected with the figures of equilibrium of rotating masses of fluid investigated by Poincaré (Acta Mathematica, vol. VIII) and Darwin (Hill. Trans., Roy. Soc., 1887). The belief that such a division of the nebulae takes place was necessary to associate the double stars with the nebulae from which it was held they had arisen by gradual condensation. This relationship between the double stars and nebulae in process of division had been impressed upon me from the forms of the equipotential surfaces which might be constructed about equal and unequal masses.

At that time the nature of the nebulae was not very well understood, and I could do no better than fall back on the figures of equilibrium of rotating masses of fluid calculated by mathematicians, as the nearest known approach to the natural process of nebular division. Yet as the nebulae evidently were not homogeneous, the analogy was never felt to be entirely satisfactory, and was used only as a rough approximation to the true process of nature. I have long looked forward to a further development of the theory of nebular fission. It was worked out last year, along with other results on the origin of the solar system (cf. *A. N.* 4308), but owing to severe illness in the early part of this year, an earlier opportunity has not occurred of presenting it to the public.

Let us return to the figure of the hour-glass or pear-shaped space about the Sun and Jove, remembering that it is nearly a figure of revolution about the *x*-axis *SJ*. Imagine this whole space filled with nebulosity such as we see in comets or in the nebulae of space. This is conceived to be an excessively tenuous medium essentially devoid of hydrostatic pressure, with the individual particles pursuing their own orbits and seldom coming into collision with others.

Then as the medium will at length become densest about the central masses *S* and *J*, it is evident that all particles moving in orbits about these bodies will be confined to the hour-glass space already explained. They may traverse it in various ways, but usually will move in planes not departing greatly from that of the circular orbit of *S* and *J*. Now as all move against resistance, they will steadily drop down nearer and nearer the

two centers of attraction. In a moderately short time many of the particles will enter Jove's sphere of influence to depart no more, while still more will pass wholly under the influence of the Sun. The rest will circulate about the two masses or pass between them, and pursue retrograde orbits about one center or the other. The condensation at these centers will increase steadily, owing to the effects of resistance, and we shall have two equal or unequal masses, according to the original supply of nebulosity as it flows into centers.

Usually there will be a large central condensation or sun, and attendant planets; but in some cases there may be a nearly equal division of the nebulosity, as in the double stars (cf. Figure 6).

The distribution of mass in a system depends on initial conditions. If as a nebula coils up and condenses under gravity, there is a considerable companion nucleus already begun, the supply of nebulosity may be such as to give a pair of nearly equal masses, with smaller satellites near each body. In some cases there will be a single remote body, and another closer pair of stars, as in triple-star systems; while in yet others the division will give quadruple and multiple stars and clusters of higher order. Such equable division takes place where the original nebula is so widespread as to permit the development

of multiple centers of attraction, all of large size and comparable in mass.

XI. The Formation of double and multiple stars and planetary systems.

It is evident from the above considerations that the resulting mass-ratio in a system depends on the supply of nebulosity and the original nuclei already begun and slowly developing in the nebula when it was still of vast extent and great tenuity. The resisting medium operates to build up the nuclei already started; and as the sphere of influence of each nucleus is thus extended, the power of capturing additional nebulosity steadily increases. In a system of two principal bodies the planet may in some cases thus rival the Sun; but in general the Sun's influence will predominate, while the remaining nebulosity will be divided among a number of planets all comparatively small.

Thus we are justified in believing that, since the stars have in general resulted from the condensation of nebular vortices, or whirl-pool nebulae, nearly all the stars have systems of planets circulating about them; but it is obvious that the double stars and spectroscopic binaries are the only attendant bodies which are sufficiently luminous or sufficiently massive to be detected with our existing instruments at the great distance of the fixed stars.

According to this view there will exist in the heavens all sizes of attendant bodies, from infinitesimal planets, such as those observed in the solar system, to double stars, with equal or comparable companions. In systems with double or multiple distribution of mass, the planets which are developed, if they are to continue to revolve in stable orbits, will have to be near the large masses, so as to keep within the closed surfaces about these centers of attraction, or at great distances from them. Probably both classes of planets may be inferred to exist in the immensity of space. But it is worth while to notice that in *double-star systems with very eccentric orbits* the region of stability about each mass is considerably narrowed; because the closed hill surface is of extremely variable radius, being very large when the stars are in apastron and very small when at periastron. The constants of energy, if we may still use that expression, for particles revolving in such eccentric systems would thus be very fluctuating, and the destructive tendency much greater than in systems with approximately circular orbits.

XII. Analogy between the dynamical division of a nebula under the secular action of a resisting medium and the rupture of the figure of equilibrium of a rotating mass of fluid calculated by mathematicians.

The form of the energy surfaces about a revolving sun and planet has been shown to be closely similar to that of a rotating and condensing mass of fluid kept in equilibrium under the pressure and attraction of its parts. The mathematical difficulties encountered in the investigation of the figures of equilibrium have proved to be nearly insuperable, and the results necessarily have been restricted to the case of fluid which is both homogeneous and incompressible, which does not accord with the conditions in actual nature. Under the circumstances it has been very difficult for the mathematician to attack the more general problem of the division of heterogeneous compressible masses, such as the nebulae have long been supposed to be.

If the above line of treatment is admissible, we see that elaborate mathematical treatment of this problem is now rendered unnecessary by the retarding and degrading influence of the resisting medium. To see what will happen in any case, all that is required is to calculate the form of the energy surfaces and draw limiting surfaces of energy with the pear-shaped figure connecting the Sun and planet. The division of the nebulosity is then necessarily effected automatically, by the resisting medium; and is in accordance with the total supply of material and its distribution in the system at some initial epoch. Of course, the exact form of the pear-shaped surface depends on the masses of the planet and its distance when the system is started, and it changes with the development of two bodies.

This is a comparatively simple conception and is capable of much more lucid treatment than that depending on figures of equilibrium of rotating masses of fluid. Nor will the variations of density in the nebular medium in general exert any unfavorable influence on the final result. It is moreover in accord with actual conditions in nature, so far as these may be inferred from the study of the nebulae, and from the theory of gases. It is not necessary to take up in this paper the problem of the density of the nebulosity in the pear-shaped or hour-glass space; but we may remark that the problem has been treated from different standpoints by the following well-known authors :

1) J. Homer Lane (*American Journal of Science*, July, 1870), who considers the gaseous theory of the Sun's constitution, and develops the theory of a gaseous mass in convective equilibrium.

2) Lord Kelvin (Popular Lectures and Addresses, p. 376-429), who treats the gravitational theory of the Sun's heat, and (in Proc. Roy. Soc. of Edinburgh, Vol. 28, Part IV, March 9, 1908) solves the problem of a spherical gaseous nebula under several hypotheses.

3) A. Ritter, who treats various problems in Wiedemann's Annalen, 1878-1882.

4) G. W. Hill, in Annals of Mathematics (Vol. 4, No. 1, February, 1888).

5) G. H. Darwin, Phil. Trans., Roy. Soc., Nov. 15, 1888. He treats the mechanical condition of a swarm of meteorites from the gaseous standpoint.

6) T. J. J. See, who treats very fully the monatomic theory in *A. N.* 4053, November, 1905.

Among these various papers Darwin's is the only one which considers the mass to be a swarm of meteorites; but even he adopts the theory of gases, which, however, is only partially valid for nebular conditions. Probably the law of density found by the present writer in *A. N.* 4053, which makes the density increase quite slowly and become exactly six times the mean density at the center, is that which will, on the whole, accord best with the conditions of the nebulae. In the present paper it is sufficient to remark that the density of the nebulosity or cosmical dust certainly increases toward each center, but the rate of increase is likely to be less rapid than in the case of ordinary gases, which makes the central density about twenty-three times the mean density,

Leaving these details to the future, it is evident that the process of automatic division, by degradation of energy under the action of a resisting medium, always going on in a nebula, is comparatively simple; and easily understood in connection with the closed surfaces which operate to capture the particles of the nebulosity. This slow dynamical process, by which particles are gathered in one by one, takes, indeed, a very long time; because it depends on the degradation of the energy under resistance, but its mode of operation is sure, and the final outcome beyond doubt.

Though this new line of thought deprives us of the principles

of hydrostatic pressure, heretofore largely invoked in these researches on cosmical evolution, and we have to give up the historical point of view as largely inapplicable to the nebulae, yet as it can no longer be held that the attendant masses are detached by rotation proceeding from the center of the system, as formerly believed, perhaps we shall have less need for the theory of hydrostatics. The figures of the connecting energy surfaces, as defining the boundaries of capture, may well take the place of the figures of equilibrium of rotating masses of fluid. The method of attack here adopted is therefore much simpler, and possibly less exact, than those followed by Poincaré and Darwin; and although the conclusions drawn from the two lines of investigation are similar, one cannot help thinking that this latter process conforms much more closely to the law of nature than that based on figures of equilibrium. This process of automatic division we may call *nebular fission*, in contrast to the process of *fluid fission*, found from the researches of mathematicians on the figures of equilibrium of rotating masses of fluid.

In conclusion it only remains to add that the writer's indebtedness to the researches of Hill, Poincaré and Darwin, for valuable suggestions in connection with the problems of Cosmical Evolution, has been sufficiently pointed out in the papers published during the past eighteen years; but he may here emphasize the profound significance of the famous Researches in the Lunar Theory, of the Classic Methods Nouvelles de la Mécanique Céleste, and of the celebrated Memoir on Periodic Orbits, without which it is to be feared the problems here attacked would have remained insoluble. Imperfect as this feeble effort may be, he entertains the hope that it has considerably cleared up the problem of the capture, and transformation of the orbits, of satellites, and of the fission of nebulae under the secular action of a resisting medium, on which cosmical evolution so largely depends.

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May 6, 1909.

THE ASSUMED PLANET BEYOND NEPTUNE.

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For Popular Astronomy.

Three independent investigators have recently attempted to locate this planet by means of its perturbations of Uranus. A comparison of their results may, therefore, prove of interest. M. Lau, in 1899, concluded that it was necessary to assume the existence of two unknown planets. The writer, in 1908, announced the position of one, and early in 1909 published his results in detail, H. A. 61, Part 2. In 1909 M. Gaillot published an abstract of his computations, also locating two unknown planets, C. R. 148, 754. The first and last researches were conducted by analytical methods analogous to those used by Adams and Le Verrier. The writer used a graphical method of his own device, which was founded on a suggestion of Sir John Herschel.

He did not feel the necessity of proposing the existence of two planets, but it is obvious that the perturbations could be explained by locating a planet in either of two positions, differing from one another by about 180° in longitude. This fact was first pointed out by Le Verrier, and recently by M. Lau, *Bulle. Astron.* 1903, 252. It is also shown very clearly in the curves published by the writer, notably Figures 16 and 26. The writer chose the position which the graphical method indicated as the more probable of the two. In the following table, for purposes of comparison, however, he also gives the other position, distinguishing it by inserting it in parentheses and following it by a $\pm$ sign, to indicate that it is only approximate. Undoubtedly the observed deviations from theory could be somewhat reduced by assuming the existence of two unknown planets, and could probably be still further reduced by assuming three or four, at proper locations. The writer is quite prepared to admit the existence of several unknown outer planets, but in his work he found that the assumption of one was sufficient to reduce the outstanding errors of position, to a value less than the probable accidental errors, due to uncertainties in the perturbations of the known planets, and errors in the earlier observations.

In the following table the positions are all reduced to the epoch of 1900. In the second column, first and third lines, the first values of the longitudes are those given by M. Gaillot, the second those

COMPARSION OF RESULTS (1900).

Computer	Longitude	Distance	Mass	Longitude	Distance	Mass
	° °			°		
Lau	269, 300	46	$\frac{1}{33,000}$	153	75	
Pickering	(286) ±	(52)		106	52	$\frac{1}{168,000}$
Gaillot	271, 285	44	$\frac{1}{64,000}$	108	66	$\frac{1}{14,000}$

given to the writer in a letter by M. Lau. Why they should differ from one another is not clear, and the writer has not yet seen M. Lau's original publication. If we assume that each computer knew best the location of his own planet in 1900, we obtain the longitudes 300° and 271°, of which the mean 285°.5 agrees practically with the parenthetical value given by the writer. Indeed, the greatest deviation found, M. Gaillot's value of M. Lau's planet, only differs from it by 17°.

Regarding the longitude of the second planet, given in the fifth column, M. Gaillot and the writer are in practical agreement, but M. Lau differs appreciably from them. The value of the longitude of M. Lau's planet it should be stated was taken from M. Gaillot's paper. The distance of the writer's planet, 52, is intermediate between the distances of the two planets of the other computers. The mean distance of M. Lau's two planets is 60.5, of M. Gaillot's 55. The mass of the writer's planet is appreciably smaller than the others, although all agree that the mass of the inner planet must be distinctly less than that of Neptune, which is $\frac{1}{19,500}$. Had the writer adopted the parenthetical longitude 286°, he would have had to increase the mass of his planet, and perhaps made it equal to that given by M. Gaillot.

Summarizing the results, it would appear if the deviations between the observed and computed positions of Uranus are really due to the perturbing action of a hitherto unknown outside planet or planets, that as the result of these three independent researches, the unknown body in 1900 must have been located either between longitudes 269° and 300°, or between longitudes 106° and 153°. The limits are therefore 31° and 47° apart respectively.

M. Lau writes me "If we find no planet between 260° and 320° of longitude (at the present time) it is absolutely certain that there exists none beyond Neptune." The writer's views are not so pronounced. While he considers longitude 106°, in

1900, as the more probable, he admits that the planet at that time might have been located near longitude 286°. M. Gaillot, with still greater prudence, expects to find a planet located in 1900, in both longitudes 108° and 271°.

To those who may be interested in searching for this elusive body, the writer would suggest while it would seem at first probable that it would be found near the ecliptic; that this by no means necessarily follows. The orbits of Jupiter's sixth and seventh satellites are inclined to the plane of the orbits of the brighter ones by 28° and 26° respectively. It is quite possible, and even probable, therefore, that the orbit of this small and remote planet may be similarly inclined to the plane of the ecliptic.

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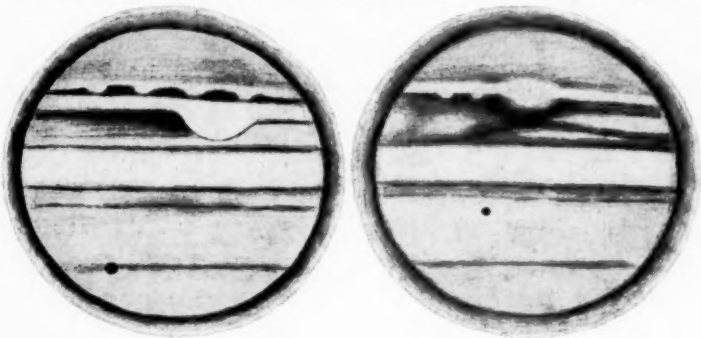
JUPITER IN 1909.

IRENE E. TOYE WARNER

FOR POPULAR ASTRONOMY.

The planet Jupiter has been a most interesting study during this last apparation. The south temperate belt has varied in intensity of coloring from night to night, being sometimes extremely sharp and clear, and much indented with white spots along its southern edge, and at others more diffused and broken. On May 23 at 9^h 10^m the south equatorial and south temperate belts seemed to be in a very active condition. I noticed a much larger white spot than usual in the south temperate



May 19, 9^h 45^m (P. 300) May 23, 9^h 10^m (P. 300)

SATELLITE IV SHADOW IN TRANSIT.

belt, it was very much like the red spot hollow in shape, but not quite so long and deep. The S. S. temperate belt was also curved just above the spot, the brilliant material of which the latter was composed appearing to have forced its way into the latter belt.

The red spot has been too faint to observe but the hollow or bay in which it lies has varied in structure with the greatest rapidity. On April 4, a finely pencilled line connected the "f" shoulder of the hollow with the south temperate belt; on the 6th it had become faint and spread out like a cloudy mass on the south tropical zone, and by the 16th it had quite disappeared leaving the tropical zone clear and white.

On the whole the chief belts have been sharply defined and well marked, and the equatorial zone has been very brilliant. Markings on the latter were extremely faint and generally quite invisible in my 12.6-inch Calver Reflector. The round black spot on the north hemisphere in the accompanying drawing on May 19 at 9^h45^m is the shadow of Satellite IV which commenced transit at $7^h\ 44^m$ and ended at $11^h\ 38^m$; the smaller black spot in transit on May 23 at $9^h\ 10^m$ is Satellite III.

I observed the planet on thirty-three evenings and made numerous drawings, the power used being about 300.

Bristol, England.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

FOR POPULAR ASTRONOMY.

Part IV. (Continued.)

THE TERRESTRIAL ATMOSPHERE. ITS VOLUME, EXTENT, DENSITY, PRESSURE, TEMPERATURE AND THE METEOROLOGICAL EFFECTS CAUSED THEREIN BY THE SOLAR ELECTRO-MAGNETIC RADIATIONS.

The distance of the zones so separated is found by multiplying the initial radius, in each case, by the factor $\sqrt{\frac{1}{3}} = 0.5776$ and continuing the operation, in a series, down to the present radius of each planet, for reasons stated on preceding pages, and in the following tables are set forth the results of my computations in this connection.

In the first column, for each planet, are the several radii of

the zones of matter separated by the forces developed by the process of compression under the action of the force of gravity of the condensing mass; in the second column is given the width of each zone as indicated by the limiting distances which are twenty-five per cent on each side of the mean distance of each zone; in the third column is the number, or the name, of each known satellite having its aphelion point indicating, approximately, the place of its origin, within said zone, and in the fourth column is given the aphelion distance—so far as it is determinable—of each of said satellites, the mean distance being adopted in cases where the eccentricity of the orbit of the satellite is either unknown, or so small as to be insignificant.

TABLE I.

Earth, Initial Radius = 380				Mars, Initial Radius = 580			
Radius of Zone	Width of Zone	Satellites in Zone	Aph. Dist. of Satellites	Radius of Zone	Width of Zone	Satellites in Zone	Aph. Dist. of Satellites
220	275 - 165			330	412 - 248		
130	160 - 98			190	237 - 143		
72	90 - 54	Moon	63	110	138 - 82		
42	52 - 32			63	79 - 47		
24	30 - 18			36	45 - 27		
14	17 - 11			21	26 - 16		
8.0	10.0- 6.0			12	15 - 9		
4.6	5.7- 3.5			6.9	8.6- 5 2	Deimos	6.4
2.6	3.2- 2.0			4.0	5.0- 3 0		
1.5	1.9- 1.1			2 3	2.9- 1.7	Phobos	2.4

Jupiter, Initial Radius = 1230				Saturn, Initial Radius = 1750			
Radius of Zone	Width of Zone	Satellites in Zone	Aph. Dist. of Satellites	Radius of Zone	Width of Zone	Satellites in Zone	Aph. Dist. of Satellites
710	887 - 533			1000	1250 - 750		
410	512 - 308	VIII	400	583	729 - 437		
235	294 - 176			337	421 - 253		
135	169 - 101	VI&VII	164	190	237 - 143	IX	23.7
78	97 - 59			110	138 - 82		
45	56 - 34			66	82 - 50	VIII	71.8
26	32 - 20	IV	27.0	37	46 - 28	VII	28.0
15	19 - 11	III	15.3	22	27 - 17	VI	22.8
8.5	10.6- 6.4	II	9.6	12	15 0- 9	V	9.8
4.9	6.1- 3.7	I	6.0	7.2	9.0- 5.4	III&IV	5.4&7.0
2 8	3.5- 2.1	V	2.6	4.1	5.1- 3.1	I & II	3.6&4 3
1.6	2.0- 1.2			2.4	3.0- 1.8	Ring	2.1

TABLE I.—Continued.

Uranus, Initial Radius = 3390				Neptune, Initial Radius = 5600			
Radius of Zone	Width of Zone	Satellites in Zone	Aph. Dist. of Satellites	Radius of Zone	Width of Zone	Satellites in Zone	Aph. Dist. of Satellites
1900	2375 -1425			3240	4050 -2430		
1090	1362 - 818			1850	2312 -1388		
630	788 - 472			1066	1333 - 799		
360	450 - 270			616	770 - 462		
210	262 - 158			355	444 - 266		
120	150 - 90			250	312 - 188		
69	86 - 52			120	150 - 90		
41	51 - 31			68	85 - 51		
23	29 - 17	III&IV	17.0&23.0	39	49 - 29		
13	16 - 10	II	10.4	22	27 - 17		
7.8	9.8- 5.8	I	7.4	13	16 - 10	I	12
4.5	5.5- 3.5			7.4	9.2- 5.6		
2.6	3.2- 2.0			4.3	5.4- 3.2		
1.5	1.9- 1.1			2.5	3.1- 2.5		
				1.4	1.8- 1.0		

An inspection of these tables shows clearly that the aphelion distances of all the known satellites fall in some one, or other, of the zones of matter separated from the condensing masses that have formed the planets, just as the aphelion distances of all the known planets and periodic comets are situated in one, or other, of the zones of matter detached from the primitive contracting solar nebula, as indicated in the table in the February (1908) number of POPULAR ASTRONOMY--a most significant fact, as will be demonstrated.

An inspection of Table I shows that in the case of all the planets having known satellites, the point of greatest distance of each of the latter lies in some one, or other, of the zones of matter detached by the process indicated in my theory of their development, nearly all of them being comparatively close to the middle of the respective zones. In the case of Jupiter, and also of Saturn, one, or more, satellites are found in a majority of the zones, the middle of Saturn's "ring" which, doubtless, is composed of myriads of minute satellites, following the general law of development, and it is highly probable that there are others that may, in the future, be discovered in some of the apparently unoccupied zones. The four, quite recently discovered satellites of Jupiter, as well as the two now known to revolve around Mars, are all quite close to the centers of their respective

zones, and their existence might have been suspected prior to their discovery had the results of my investigation in this connection been then obtained.

In the case of the Earth, there is only one occupied zone this being that in which the Moon lies and from the matter whereof our satellite has been formed, but it would be a perfectly legitimate inference that bodies of much smaller dimensions and also diffused matter, exist in all of the numerous zones surrounding our globe, just as do the comets (some of which are accompanied by swarms of meteors) around the Sun. In general, these bodies are too small to be detected, but their presence may account for some of the transits of minute dark objects across the Sun's disk that have been reported from time to time, although such reports have been received with incredulity by scientists; but when, by perturbative action, the distance of the "perigee" of the orbit of any one of these bodies becomes less than the radius, or semi-diameter of our globe, they plunge through the atmosphere, become incandescent by the conversion of their lost motion into heat, and fall upon the surface of the Earth as "aerolites", or stony meteors, which are composed, almost wholly, of silicon and its compounds which constituted by far, the greater part of the superficial matter of our globe. Aerolites have been regarded by many persons as bodies ejected from volcanoes, either on the Moon or the Earth, with a velocity sufficiently great to carry them so far beyond either body that they revolve in orbits around the Earth, but as there is no evidence to prove that there is, or has been, any volcanic action on either the Earth or the Moon, sufficiently great to develop the requisite velocity, this hypothesis has not been generally accepted by scientists, but under that which I have advanced, just above, their origin becomes quite apparent, my hypothesis in this connection accounting well for all the observed facts and phenomena. I refer, of course, only to the sporadic meteors, or fireballs, called "aerolites" (which constitute by far the greater number of these falls, although some , if not all, of the iron meteorites may have the same origin) and not to the meteors constituting the "showers" accompanying, or moving in the orbits of certain comets.

In the first column of Table II are set forth the mean distances of the centers of the zones of gaseous matter detached in the process of development of the solar system from the primitive gaseous nebula, according to my theory thereof, these distances extending from the outermost limit of the original nebula at

38,554 units, at which the matter of the nebula was at the density, and pressure of the ether in, and from, which it was developed, down to the present surface of the Sun, the "astronomical unit", being the mean distance of the Sun from the Earth, this unit being taken as 92,800,000 miles. In the second column are the widths of the zones which average twenty-five per cent of the mean distance itself, on each side of the center of the zone, the difference between the lower limiting value on each line and the upper limiting value on the line following, constituting the width of the space between each zone, this averaging about five per cent of the mean distance of the zone, which is about that of the comparatively empty spaces constituting the dark lanes, or rifts, in the great nebula in Andromeda, which, as I have pointed out, is very similar in nature and dimensions to the primitive nebula whence the solar system has been developed.

TABLE II.

Mean Distances of Zones	Widths of Zones	Planets in Zones	Number of Comets in Zones
38,554	48,192 —28,916		2
22,259	27,824 —16,694		
12,850	16,063 — 9,639		
7,420	9,275 — 5,565		
4,284	5,355 — 3,213		2
2,474	3,092 — 1,856		4
1,428	1,785 — 1,071		3
824	1,030 — 618		9
476	595 — 357		8
275	344 — 206		7
159	199 — 119		6
92	122 — 69		7
53	66 — 40		2
31.0	39 — 23	Neptune	7
18.0	22 — 14	Uranus	2
10.0	13 — 8	Saturn	3
5.9	7.4 — 4.4	Jupiter	34
3.4	4.2 — 2.6	Asteroids	1
2.0	2.5 — 1.5	Mars	
1.13	1.41 — 0.85	Earth	
0.65	0.81 — 0.49	Venus	
0.38	0.47 — 0.29	Mercury	
0.2171	0.2714— 0.1628		
0.1256	0.1570— 0.0942		
0.0725	0.0906— 0.0544		
0.0418	0.0522— 0.0314		
0.0241	0.0301— 0.0181		
0.0140	0.0175— 0.0105		
0.0081	9.0101— 0.0061		
0.0047	0.0058— 0.0036		

In the third column are set forth the names of the planetary bodies in each zone, so far as known, the zones thus occupied constituting only a comparatively small portion of the whole num-

ber ; but, just as in the case of the planets and their satellites shown in Table I, in some, if not all, of these zones planetary bodies, some of possibly great dimensions, and others small like the asteroids, may exist and be discovered in the future, such bodies having been suspected at certain distances beyond the orbit of Neptune and also within that of Mercury.

The aphelion distances, mean distances, and periodic times set forth in Table III for the comets whereof the aphelion points lie near the orbit of Jupiter, I have derived from the very complete table of elements included in Professor William W. Payne's paper published in the April (1906) number of POPULAR ASTRONOMY, while the aforesaid quantities in the case of nearly all the other comets included in Table III, I have computed from the elements of cometary orbits tabulated in Watson's Theoretical Astronomy, which tabulation includes 267 comets with orbits of all kinds,—elliptical, parabolic and hyperbolic—observed from the year 66 B. C. to, and including, 1867 A. D. But the observations of all those which appeared prior to the invention, or discovery of the telescope,—or even some time thereafter,—could not have been sufficiently precise as to furnish the requisite data for the computation of definite elliptical elements, so that all up to that time, or about 1680 A. D., as well as those observed at more than one return and duplicated in Watson's Table aforesaid should be omitted from the whole number examined, and there would then be, roughly, about 200 nearly one half of which move in elliptical orbits, these being the comets included in Table III, nearly all the rest moving in parabolic orbits, and a few, apparently, in hyperbolas; but, as I have remarked, had the observations in the two last cases been sufficiently numerous and extended over an adequately long period of visibility, and had the planes of their orbits been most favorably situated with respect to that of the Earth, practically all would probably be found to move in elliptical orbits, or in other words, would be found to be more, or less, permanent members of the solar system, as are the planets. I am extending Table III to include all the periodic comets discovered up to nearly the present year, some, or all of which, I think, will be found to have their aphelion points within one, or other, of the zones defined in Table II, while some may be assigned to the apparently unoccupied zones near the outer limit of the solar nebula. In any event, I think that my hypothesis of the origin of comets and their permanence as members of the solar system, is corroborated by the data in Table III.

In Table III are set forth, in the first column of the table corresponding to each mean distance taken from Table II, the names of the periodic comets, the aphelion distances whereof are, as I have found by my computation within about twenty-five per cent of the mean distance on each side of the center of the zone, their aphelion distances being set forth in the second column and period of revolution in the fourth column while the distances of the aphelion point in each case from the center of the zone and expressed as a fraction of the mean distance is set forth in the third column, this aphelion distance being, according to my theory, very approximately that at which each comet was formed from the gaseous matter of the solar nebula, the aphelion distance of each known planet being also placed at the head of its proper table in comparison with the mean distance of its zone.

TABLE III.

Comet	Aph. Dist.	Diff. from Mean	Period Years
Mean Distance of Zone = 3.4			
Mean Aph. Dist. of Asteroids = 3.5			
Encke	4.1	+0.21	3.3
Mean Distance of Zone = 10.0			
Aph. Dist. of Saturn = 10.1			
1846 VI_1	9.4	−0.06	12.8
1855 II	11.2	+0.12	14.3
1858 I_2	10.4	+0.04	13.7
1. Peters, 2. Tuttle			
Mean Distance of Zone = 18.0			
Aphelion Distance of Uranus = 20.1			
1866 I_1	19.7	+0.09	33.2
1867 I_2	19.3	+0.07	33.6
1. Tempel, 2. Stephans			
Mean Distance of Zone = 31.0			
Aph. Dist. of Neptune = 30.3			
1769	32.7	+0.06	65.5
1812_1	33.4	+0.08	70.7
1815_2	34.0	+0.10	74.2
1835_3	35.4	+0.14	76.4
1846 IV	34.3	+0.11	72.9
1847 V	35.1	+0.13	75.0
1852 IV	29.6	−0.05	61.0
1. Pons, 2. Olbers, 3. Halley			
Mean Distance of Zone = 53			
1683	66	+0.25	190
1862 III	49	−0.08	124

Comet	Aph. Dist.	Diff. from Mean	Period Years
Mean Distance of Zone = 5.9			
Aphelion Distance of Jupiter = 5.5			
1678	5.0	−0.18	5.4
1766 II_1	5.5	−0.07	5.0
1770 I_2	5.7	−0.04	5.6
1783 IV_3	4.9	−0.24	5.9
1819	5.5	−0.07	5.6
1819 IV_4	4.8	−0.23	4.8
1844 I_5	5.0	−0.18	5.5
1858 III_6	5.9	0.00	6.6
1873 II	5.6	−0.05	6.7
1881 V_7	7.8	+0.32	8.8
1884 II_8	4.9	−0.24	5.4
1886 IV_9	5.0	−0.18	5.6
1889 V	5.4	−0.09	7.1
1889 VI_{10}	7.0	+0.18	8.5
1890 VII_{11}	5.1	−0.16	6.4
1892 V_8	5.5	−0.07	6.5
1894 I_7	6.5	+0.10	7.4
1895 II_{10}	6.2	+0.05	7.2
1896 V_{12}	5.6	−0.05	6.6
1896 VII_{13}	5.9	0.00	6.5
1900 III_{12}	6.2	+0.05	6.8
1905 II_{14}	6.1	+0.05	7.2
Tempel	4.7	−0.25	5.3
Brorsen	5.6	−0.05	5.5
Tempel-Swift	5.2	−0.11	5.7
Winnecke	5.6	−0.05	5.8
Tempel	5.6	−0.05	6.5
Swift	5.2	−0.11	6.4
Finlay	5.2	−0.11	6.6
D'Arrest	5.8	−0.02	6.7
Biela	6.2	+0.05	6.7
Wolf	5.6	−0.05	6.8
Holmes	5.1	−0.16	6.9
Faye	5.9	0.00	7.4

TABLE III.—Continued.

Mean Distance of Zone = 92

Comet	Aph. Dist.	Diff. from Mean	Period Years
1680	83	−0.18	267
1793	111	+0.21	421
1840 IV	98	+0.07	351
1845 III	79	−0.16	250
1857 IV	75	−0.23	238
1861 I	110	+0.21	415
1861 II	112	+0.21	422

Mean Distance of Zone = 275

1807	286	+0.04	1,715
1846 VII	312	+0.14	1,967
1846 VIII	359	+0.30	2,429
1853 I	225	−0.22	1,187
1854 IV	239	−0.15	1,309
1858 V_1	312	+0.13	1,950
1860 III	211	−0.13	1,093

1. Donati

Mean Distance of Zone = 824

1580	860	+0.04	8,921
1822 IV	618	−0.32	5,537
1847 I	978	+0.19	12,580
1849 III	823	0.00	8,472
1851 III	630	−0.31	5,511
1855 IV	897	+0.09	9,468
1857 III	734	−0.12	7,040
1857 VI	777	−0.06	7,687
1874 III_1	958	+0.16	10,590

1. Coggia

Mean Distance of Zone = 1,428

1840 II	1,151	−0.24	13,056
1847 IV	1,155	−0.24	13,855
1849 II	1,096	−0.30	12,875

(Observers referred to by number.)

1. Helfenzrieder, 2. Lexell, 3. Pigott, 4. Blanpain, 5. De Vico, 6. Tuttle, 7. Denning, 8. Barnard, 9. Brooks, 10. Swift, 11. Spitaler, 12. Giacobini, 13. Perrine, 14. Borrelly

Mean Distance of Zone = 159

Comet	Aph. Dist.	Diff. from Mean	Period Years
1811 II	181	+0.14	878
1843 I	132	−0.21	412
1846 VII	125	−0.27	504
1853 II	169	+0.06	787
1854 V	198	+0.24	998
1855 VI	124	−0.28	500

Mean Distance of Zone = 476

1763	437	−0.09	3,303
1811 I	422	−0.13	3,108
1825 IV	542	+0.14	4,487
1827 II	378	−0.27	3,078
1846 I	388	−0.22	2,720
1857 V	364	−0.30	2,500
1864 I	563	+0.18	3,178
1871	597	+0.25	4,951

Mean Distance of Zone = 2,474

1847 III	2,500	+0.01	74,140
1850 I	1,883	−0.31	28,807
1857 I	1,964	−0.25	29,977
1874 V	2,551	+0.03	45,593

Mean Distance of Zone = 4,284

1780 I	3,566	−0.20	73,250
1844 II	4,267	0.00	98,582

Mean Distance of Zone = 38,554
Outer Limit of Solar Nebula

1863 I	29,990	−0.28	2,003,900
1864 II	39,615	+0.03	2,540,500

We know that a comet, or any other heavenly body, moving around the Sun in a definite orbit be the same circular, elliptical, parabolic, or hyperbolic may have its orbital velocity increased, or decreased, and the elements of its orbit changed, by a comparatively near approach to a planet of considerable mass; thus a periodic comet known to move in a definite elliptical orbit around the Sun, may, by reason of a close approach to Jupiter, Saturn, the Earth, or any other planet, have its orbit changed into a parabola, or an hyperbola, open curves in which the comet would *theoretically* move forever away from the Sun, and eventually into some other stellar system; or conversely,

one moving from such an outside system in said open curves might have its orbit changed into an ellipse and become a more, or less, permanent member of the solar system, and in the case of a sufficiently close approach to a planet, the attractive force of the latter might become so great that the comet would be wrested from the controlling influence of the Sun and be brought under that of the planet around which it would revolve as a satellite. But the motion of any comet out in space, far from the Sun, is very slow and the existence of a resisting medium in space has been suspected, in fact the luminiferous ether itself which fills all space, at least to the distance of the most remote star visible in the most powerful telescopes, must act as a resisting medium tenuous though it be, and a comet moving in an open curve, away from the Sun, through such a medium could not progress indefinitely beyond the controlling influence of the latter and would, eventually, be brought back into the solar system; so that, if any of them really move, in parabolic, or hyperbolic, orbits while visible to us, these conditions can be only temporary; conversely, no comet under such condition could come into the solar system from a stellar one and all, in the ultimate analysis, will be found to be members of the former system, under my hypothesis.

The aphelia of all the comets set forth in Table III are within the limit of twenty-five or thirty per cent of the mean distance of their respective zones, on each side of the center thereof, most of them being within twelve or fifteen per cent, and many practically at the center of the zone, as are the respective planets the aphelia whereof are set forth in said Table, the comets being quite equally distributed on both sides of the center as indicated by the plus and minus signs in each third column of Table III, so that the mean of all the aphelia in each group is found to be very near the center of each zone; so that, although the zones are of considerable width the mean of the aphelion distances of all the comets in each zone falls within a comparatively narrow belt near the center of each zone. A conclusion to which my investigation of this subject inevitably leads is that while it is possible—and, in some cases even probable—that some of the comets in the zones wherein lie also the aphelia of the great planets have been so to speak, *captured* by the latter—particularly by the planet Jupiter—their apparent connection, or relation, with these planets is most likely due to the simple fact that they have been formed at, or near, their respective aphelia, in and from, the same nebulous matter of the zones whence the planets

themselves have been formed and that all these comets have been practically like these planets permanent members of the solar system, and will continue as such *ad infinitum* no matter how much temporary perturbation and consequent change of the elements of their orbits they may undergo and that, therefore, while the "capture theory" of the origin of these comets is in accordance with well-known mathematical principles of analytical mechanics, and is plausible it is one that does not necessarily hold good in the light of the above stated facts and tabulated figures derived from my rigorous mathematical investigation of this subject.

Furthermore, it is clearly indicated in Table I that all the known satellites of any planet possessing such bodies, have been formed in the zones of nebulous, or gaseous, matter detached from the minor condensations, or secondary nebulae, which, after contraction, have become the known planets, just as have been the planets and comets in the zones of matter detached from the primitive, condensing solar nebula at the mean distances indicated in Table III. Therefore the method of development of the satellites, as well as of their primaries, is clearly explicable under my theory in this connection, without recourse to any other theory such as that of the action of "tidal friction" in the development of the Earth-Moon system, a theory which, while it to a certain extent may be upheld by a rigorous mathematical analysis as a *possibility*, is not by any means as susceptible of proof by the agreement of the theory with the facts of observation, as is the one that I have advanced in preceding parts of this paper, and subjected to such a comparison between theory and observation—the only legitimate and sufficient test of the truth of any scientific theory.

In fine, the process of derivation and development of the solar system in its entirety (planets, satellites, comets and even diffused gaseous and solid matter) from a primitive gaseous nebula is clearly indicated in the three tables above set forth this gaseous matter of this nebula having, according to my theory, been generated in, and from, the most simple, fundamental, gaseous matter known as the "lumiferous ether", it being, "in the beginning" at the same density, absolute temperature, and pressure as said ether, all of which quantities, as I have demonstrated in a preceding part, are extremely low, yet of finite values. The compression of this primitively, extremely cold, nebulous matter, under the action of its own force of gravity directed toward the center of the mass, slowly generated heat

therein, two-thirds of which has been radiated and one-third retained (agreeably to a definite law derived through my theory) in said mass, the heat so retained giving to the condensed mass which is now the Sun, its maximum absolute temperature of, roundly, 13,400 degrees Fahrenheit, while the portion radiated has, under my theory, had the effect of antagonizing the force of gravity of the condensing nebulous mass and therefore of detaching therefrom zones of gaseous matter at certain intervals defined by the law that I have stated in preceding pages. Unless *every* minute portion of the nebulous matter undergoing such compression, fell directly toward the center of the mass—a condition that is so improbable as to amount, practically, to a *physical possibility*—the condensing matter must have taken up a motion of rotation around the center of gravity of the mass, the direction of the motion, and the plane of rotation, being fixed by that of the major portion of the nebulous mass, this motion of rotation being, in reality, as I have pointed out an *orbital* motion under the laws of central forces, or at least, a derivative of such motion, the condensing, or falling, portions of gaseous matter assuming a roughly spiral form, in zones separated by dark rifts or "lanes", as is most clearly and forcibly exemplified in the case of the "great nebula" in Andromeda so beautifully depicted in both the Ritchey and Roberts photographs thereof. Furthermore, unless the density of the whole gaseous mass under compression increased with absolute uniformity toward the center throughout its volume (which condition is also *practically* a physical impossibility) minor centers of condensation must have formed about the points where the density exceeded, in even the most minute degree, that of the surrounding matter and this action, under my theory, has resulted in the formation of the planetary bodies whereof the satellites are *tertiary* condensations formed in a precisely analogous manner under the same laws of development as in the case of the condensation of the great primary solar nebula.

St. Paul, Minnesota.

To be continued.

MEETING OF THE BRITISH ASSOCIATION AT WINNIPEG.*

J. J. THOMSON

I have had the privilege of having as pupils students from your universities as well as from those of New Zealand, Australia, and the United States, and have thus had opportunities of comparing the effect on the best men of the educational system in force at your universities with that which prevails in the older English universities. Well, as the result, I have come to the conclusion that there is a good deal in the latter system which you have been wise not to imitate. The chief evil from which we at Cambridge suffer and which you have avoided is, I am convinced, the excessive competition for scholarships which confronts our students at almost every stage of their education. You may form some estimate of the prevalence of these scholarships if I tell you that the Colleges in the University of Cambridge alone give more than £35,000 a year in scholarships to under-graduates, and I suppose the case is much the same at Oxford. The result of this is that preparation for these scholarships dominates the education of the great majority of the cleverer boys who come to these universities, and indeed in some quarters it seems to be held that the chief duty of a school-master, and the best test of his efficiency, is to make his boys get scholarships. The preparation for the scholarship too often means that about two years before the examination the boy begins to specialize, and from the age of sixteen does little else than the subject, be it mathematics, classics, or natural science, for which he wishes to get a scholarship; then, on entering the university, he spends three or four years studying the same subject before he takes his degree, when his real life-work ought to begin. How has this training fitted him for this work?

The premature specialization fostered by the preparation for these scholarships injures the student by depriving him of adequate literary culture, while when it extends, as it often does, to specialization in one or two branches of science, it retards the progress of science by tending to isolate one science from another. The boundaries between the sciences are arbitrary, and tend to disappear as science progresses. The principles of one

* Extracts from the President's address reprinted from *The Observatory*, No. 413.

science often find most striking and suggestive illustrations in the phenomena of another. Thus, for example, the physicist finds in astronomy that effects he has observed in the laboratory are illustrated on the grand scale in the Sun and stars. No better illustration of this could be given than Professor Hale's recent discovery of the Zeeman effect in the light from sun-spots; in chemistry, too, the physicist finds in the behavior of whole series of reactions illustrations of the great laws of the thermodynamics, while if he turns to the biological sciences he is confronted by problems, mostly unsolved, of unsurpassed interest. Consider for a moment the problem presented by almost any plant— the characteristic and often exquisite detail of flower, leaf, and habit—and remember that the mechanism which controls this almost infinite complexity was once contained in a seed perhaps hardly large enough to be visible. We have here one of the most entrancing problems in chemistry and physics it is possible to conceive.

Again, the specialization prevalent in schools often prevents students of science from acquiring sufficient knowledge of mathematics; it is true that most of those who study physics do some mathematics, but I hold that, in general, they do not do enough, and that they are not as efficient physicists as they would be if they had a wider knowledge of that subject. There seems at present a tendency in some quarters to discourage the use of mathematics in physics; indeed, one might infer, from the statements of some writers in quasi-scientific journals, that ignorance of mathematics is almost a virtue. If this is so, then surely of all the virtues this is the easiest and most prevalent.

I do not for a moment urge that the physicist should confine himself to looking at his problems from the mathematical point of view; on the contrary, I think a famous French mathematician and physicist was guilty of only a slight exaggeration when he said that no discovery was really important or properly understood by its author unless and until he could explain it to the first man he met in the street.

The history of pure mathematics shows that many of the most important branches of the subject have arisen from the attempts made to get a mathematical solution of a problem suggested by physics. Thus the differential calculus arose from attempts to deal with the problem of moving bodies. Fourier's theorem resulted from attempts to deal with the vibrations of strings and the conduction of heat; indeed, it would seem that the most fruitful crop of scientific ideas is produced by cross-

fertilization between the mind and some definite fact, and that the mind by itself is comparatively unproductive.

The period which has elapsed since the association last met in Canada has been one of almost unparalleled activity in many branches of physics, and many new and unsuspected properties of matter and electricity have been discovered. The history of this period affords a remarkable illustration of the effect which may be produced by a single discovery; for it is, I think, to the discovery of the Röntgen rays that we owe the rapidity of the progress which has recently been made in physics. A striking discovery like that of the Röntgen rays acts much like the discovery of gold in a sparsely populated country; it attracts workers who come in the first place for the gold, but who may find that the country has other products, other charms, perhaps even more valuable than the gold itself.

The study of gases exposed to Röntgen rays has revealed in such gases the presence of particles charged with electricity; some of these particles are charged with positive, others with negative electricity.

The properties of these particles have been investigated; we know the charge they carry, the speed with which they move under an electric force, the rate at which the oppositely charged ones recombine, and these investigations have thrown a new light, not only on electricity, but also on the structure of matter.

The great advantage of the electrical methods for the study of the properties of matter is due to the fact that whenever a particle is electrified it is very easily identified, whereas an uncharged molecule is most elusive; and it is only when these are present in immense numbers that we are unable to detect them.

Rutherford has shown that we can detect the presence of a single α particle. Now the α particle is a charged atom of helium; if this atom had been uncharged we should have required more than a million million of them, instead of one, before we should have been able to detect them.

We have already made considerable progress in the task of discovering what the structure of electricity is. We have known for some time that of one kind of electricity—the negative—and a very interesting one it is. We know that negative electricity is made up of units all of which are of the same kind; that these units are exceedingly small compared with even the smallest atom, for the mass of the unit is only 1/1700th part of the mass of an atom of hydrogen; that its radius is only 10^{-13} centimeter, and that these units, "corpuscles" as they have been called,

can be obtained from all substances. The size of these corpuscles is on an altogether different scale from that of atoms; the volume of a corpuscle bears to that of the atom about the same relation as that of a speck of dust to the volume of this room. Under suitable conditions they move at enormous speeds, which approach in some instances the velocity of light.

The discovery of these corpuscles is an interesting example of the way nature responds to the demands made upon her by mathematicians. Some years before the discovery of corpuscles it had been shown by a mathematical investigation that the mass of a body must be increased by a charge of electricity. After a time corpuscles were discovered, and these are so much smaller than the atom that the increase in mass due to the charge becomes not merely appreciable, but so great that, as the experiments of Kaufmann and Bucherer have shown, the whole of the mass of the corpuscle arises from its charge.

In speaking of the ether the President said :—The ether is not a fantastic creation of the speculative philosopher; it is as essential to us as the air we breathe. For we must remember that we on this Earth are not living on our own resources; we are dependent from minute to minute upon what we are getting from the Sun, and the gifts of the Sun are conveyed to us by the ether. It is to the Sun that we owe, not merely night and day, springtime and harvest, but it is the energy of the Sun, stored up in coal, in water-falls, in food, that practically does all the work of the world.

How great is the supply the Sun lavishes upon us becomes clear when we consider that the heat received by the Earth under a high Sun and a clear sky is equivalent, according to the measurements of Langley, to about 7000 horse-power per acre. Though our engineers have not yet discovered how to utilize this enormous supply of power, they will, I have not the slightest doubt, ultimately succeed in doing so; and when coal is exhausted and our water-power inadequate, it may be that this is the source from which we shall derive the energy necessary for the world's work. When that comes about, our centers of industrial activity may perhaps be transferred to the burning deserts of the Sahara, and the value of land determined by its suitability for the reception of traps to catch sunbeams.

This energy, in the interval between its departure from the Sun and its arrival at the Earth, must be in the space between them. Thus this space must contain something which, like ordinary matter, can store up energy, which can carry at an

enormous pace the energy associated with light and heat, and can, in addition, exert the enormous stresses necessary to keep the Earth circling round the Sun and the Moon round the Earth.

Speaking of radium he remarked that Professor Strutt has shown that if radium behaves in the interior of the Earth as it does at the surface, rocks similar to those in the Earth's crust cannot extend to a depth of more than forty-five miles below the surface.

It is remarkable that Professor Milne from the study of earthquake phenomena had previously come to the conclusion that rocks similar to those at the Earth's surface only descend a short distance below the surface; he estimates this distance at about thirty miles, and concludes that at a depth greater than this the Earth is fairly homogeneous.

THEORIES OF GRAVITATION.

OWEN ELY

FOR POPULAR ASTRONOMY.

To investigate the cause of gravitation we must determine whether its energy is inherent in matter or in ether: in the first case, gravitation is a wave in ether caused by some property or motion of particles; in the second, it is the direct result of an ether-pressure on matter. Such a pressure must be inactive between two particles or masses. Villemont (1707) conceived "a difference of pressure on outer and inner faces, of the fluid constituting the solar vortex, owing to an increase of its density outward from the Sun."[1] Bernouilli (1734) pictured "a central torrent continually thrown from the whole circumference of the vortex to its center, and consequently impressing on all bodies encountered by it in its path the same tendency toward the center of the vortex." These theories are echoes of Newton's suggestion that ether is less dense in and about particles. In 1750 Le Sage made a more definite attempt to explain the action of the ether. "By means of an infinite number of ultramundane corpuscles of transcendent minuteness and velocity traversing space in straight lines in all directions, atoms and masses of matter are impelled together differentially in the lines

(1) This and the quotations following are taken from "Kinetic Theories of Gravitation", by Wm. B. Taylor, Smithsonian Report, 1876.

of their reciprocal mechanical shadows, or in the direction in which the rectilinear impulses of the corpuscles are uncounterbalanced by opposing ones, from the intervention of atoms or masses." The Le Sage corpuscles would merely create a gaseous pressure of the ether on account of the constant collision of the particles and their change of direction, and the shadows would have no duration. A shadow theory can only be useful on condition that the "lines of force" are unconflicting and thus unalterable in direction.

Leray in 1869 suggested that "in the ether there exist at every point equal currents crossing each other in all directions," and Boisbaudran added, "I prefer the notion of vibrations of the ether to that of equal currents crossing each other in all directions. It is to the longitudinal vibrations of the ether that I attribute the cause of weight." The same idea was recently put forth by Charles Morris[1]. "The assumption is that the ether particles are fixed in space and possess no direct motions, not darting about in the free and irregular manner attributed to gaseous molecules, but restricted to vibratory movements like those of the molecules of matter. Were the former the case, the motions which produce the phenomena of light would be dissipated and the transmission of light waves through space could not proceed." This theory seems the only modification of an ether pressure so that it may act through straight lines; but, like his predecessors, the author fails to justify his assumption as to the motions of the ether particles. The whole theory of the lines of force may be tested by analyzing the characteristics of these motions.

The vibration of a material particle cannot be natural to itself, and in any other case than collision is caused by ether stresses. By the same consideration, the ether particle itself must be surrounded by a second ether—a cumbrous and undesirable provision. We must, then, consider whether the collison of particles could impart to each one a continuous vibrational movement, confined to a certain radius of action, synchronous in nature, and following a constant path, such as a straight line, a circle, or an ellipse. The vibration must have some such characteristics of regularity since it forms a part of the lines of force, unalterable in direction. The question arises whether a molecule pursues such a vibration in solid bodies: there seems to be no evideuce that it does. The fact is that

(1) *Journal of the Franklin Institute*, March, 1909.

the "vibrations" of heat motion consist of a "darting about" of such a molecule much as in a gas, except that they are cient time the particles of one can be detected in the other. The comparison of the ether particle to the "vibrating" molecule of solid matter gives no evidence that the former could be "fixed in space" and its movements perfectly regular.

The ether particle was vaguely pictured "swinging into a nest of resisting ether, as fixed in place as itself, compressing this in doing so, and being driven back at the opposite extremity of its swing." It is difficult to image a "swinging" particle as "fixed in place". The description does not explain why the nest of ether should be fixed also, when every particle in it is supposed to be in motion. To avoid this ambiguity simply consider the two particles in collision: each moving straight toward each other, they rebound in the same line and, meeting neighbors on the further sides in the same way, return to the identical point for collision, at the same interval of time for each vibration. This would be the simplest arrangement for a perfect vibration and would account for one line of force, constant in direction. Other similar lines would lie parallel to the first. But what about those lines at any angle with the one described? They must pass through it at every point, and its particles must therefore be a part of them also. They must vibrate in the direction of every line that passes through them, theoretically an infinite number. If the duties of the particle may still be performed by vibrating regularly in polygons or circles or in any manner not a "darting about," the system of collisions to which such vibrations would be accountable seems incomprehensible. Every collision would necessarily form such an angle of directions that both particles would rebound to meet others at certain fixed points, the latter would then follow the same action in meeting their neighbors, and thus *ad infinitum*. The complexity of such a system is merely one indication of its impossibility.

To examine the theory completely, consider another aspect of the ether's motion described by the author: "each vibrating corpuscle would cause a condensation of the ether into which it moved and . . . there would arise a condensational-rarefactional wave like that of sound, differing from the latter principally in its agent and its vastly greater rapidity." The assumption that the line of force constitutes a wave does little to expedite a logical explanation. While a longitudinal wave in ether is modified by the force of cohesion. That the molecule does oc-

casionally leave its sphere of action is plainly shown by the fact that when two metals have been pressed together a sufficonceivable and possible, it is here considered without a beginning or an ending. Each particle receives its motion from the one preceeding it, passes it on to the next, and so on to infinity: the energy of the wave, wherever it first sprang from, has passed into infinity and cannot return; an indefinite amount of energy must be constantly radiated by every particle. It might be answered that each particle also receives the energy from an indefinite number of waves passing over it. However, the whole problem of the waves and lines of force reduces to this fallacy: it is impossible for several waves of the same quality and strength to traverse the same point simultaneously. They must either re-enforce or destroy each other, as do two like sound waves or light waves when super-imposed.

These conclusions force the decision that it is improbable, if not impossible, that a store of inherent energy could be maintained in a system of interacting particles such as the ether, except in the manner attributed to gaseous molecules. Since under these conditions the motions do not act through straight lines, the ether pressure theory offers no solution of the problem of gravitation.

Finally, it is doubtful whether Morris' theory overcomes the objection to Le Sage's theory, that gravitation would be proportional to surface rather than mass. "There seems likely to be a continual action and reaction (between particles of ether and matter), an unceasing conflict between their respective energies." Because of the shadow described by Le Sage, "the particles of matter would be driven together until their aggregated energy enables them to prevent further condensation." Further, that gravitation may be proportional to mass instead of surface, "part of the ether energy would be employed in maintaining this state of compression, part of it would be taken up by the molecules and be transferred by means of them to the ether beyond, enabling it to act upon more interior molecules." There are, then, three actions of the molecule necessarily assumed: its natural heat motion is reduced by friction with the ether; it moves in the direction where the ether pressure is weakest; and it transfers the energy of the ether. The first and second might be possible effects of a pressure, but there is no evidence of a friction between matter and ether. If, for example, a "conflict between energies" takes place between the vibrations of ether particles and those of the molecules of air, which have

a speed of about 1,000 miles per hour, why is not the Earth as a whole retarded in space, since its motion is faster than that of the air molecules? The transferrence of the ether energy by the molecule cannot be assumed : for if the molecule's energy of motion is naturally less than the ether particle's (which is required to explain the effect of an ether pressure), then neither would that motion be reduced by the ether, nor could the molecule convey the ether's motion, but would simply appropriate sufficient energy to make its own kinetic energy equal that of the ether particle. These considerations illustrate the confusion to which the theory leads and show its inadequacy as so far developed.

The theory that gravitation constitutes waves caused by the energies of matter has been much discussed. Dr. Hook in 1671 first suggested the hypothesis when he observed that floating particles always gather at the center of a wave disturbance. Dr. Young, a century after Newton, wrote[1], "The effects of gravitation might be produced by a medium if its particles were repelled by all material substances", thus maintaining a rarefaction of ether about matter in accordance with Newton's suggestion. Dr. Guyot in 1832 observed that "disks of pith and paper delicately suspended near a vibrating tuning-fork" were attracted to the fork; and a bell when sounded caused the same attraction. From this he deduced that "attraction is a mechanical force consisting, first, of the rarefaction of ether between molecules, masses, or the heavenly bodies, resulting from the ceaseless vibration of the atoms of ponderable matter, and secondly, of the reaction from the exterior pressure of the ether upon the same, resulting from the general pressure of the imponderable medium which constitutes the mother-liquor of the Earth."[2] Boucheporn (1849) suggested that "the displacement of the ether by the movement of a body will produce in all parts of the fluid a sort of aspiration toward the ponit being left by its center." Lamé (1852) "determined analytically two systems of undulations in the ether of differing velocities; one system radial, or normal to the ellipsoidal surface of the wave, affecting the dilation or condensation of the medium and not concerned in optical phenomena; and the other system transverse to this in two sets, or in the direction of two tangents to the ellipsoidal wave, representing the phases of polarized light."

(1) Lectures on Natural Philosophy, vol. I., p. 616.

(2) Presse Scientique, 1861, vol. III, p. 130.

In 1870 Guthrie re-discovered the phenomena of the tuning-fork; and recently the same law of action of the condensational-rarefactional wave has been demonstrated by an elaborate apparatus, the identical theory of gravitation being deduced as before. "A metallic globe . . . is united by tubes with a cyclinder one end of which is closed by a membrane. To this membrane is attached an electro-motor, which by pushing and pulling the membrane alternately, makes rapid pulsations. The metal globe contains two air-filled india-rubber balls of different sizes. The larger is fixed firmly to the inside wall of the globe; the smaller is free to move. The whole apparatus is then filled with water and the motor set to work . . . When the vibrations of the balls (due to variation of water pressure caused by membrane's vibrations) attain a certain speed, the small ball begins to move thru the water to the larger ball, and gradually increases its speed."[1]

Before tracing further the development of the wave theory, let us consider a property of gravitation which has much to do with any hypothesis as to its cause—the rate of its propogation through space. From the records of ancient astronomers La Place was enabled to calculate that the sidereal day is not 1/100 second more nor less than in the days of Hipparchus. It is deduced from this that the speed of gravitation is practically infinite in comparison with the speed of the Earth, since otherwise the composition of the two motions would produce an angle of aberration for gravitation as it does for light: thus the direction of the Sun's attraction would be changed, the Earth's orbit would be slowly displaced, and the length of the day would not remain constant. Arago stated that "if we apply to the perturbations the maximum value which the observations allow . . . we find the velocity of the attractive force to amount to fifty millions of times the velocity of light."[2] On this estimate gravitation would reach the Earth from the nearest star in about two seconds while light requires three years for the journey. Tisserand calculated[3] by the same method that the velocity must be at least six million times that of light. From these conclusions physicists have supposed that the action of gravitation may be practically infinite. In the ether pressure theory time may be rotally eliminated as a factor, since the

(1) Literary Digest, May 15th, 1909.
(2) Popular Astronomy,, book XXIII, vol. II, p. 469, English edition.
(3) Traité de Méchanique Céleste, tome IV, p. 495.

energy of gravitation is furnished at the attracted and not the attracting particle. If gravitation is absolutely instantaneous the wave theory would be untenable; for no motion could traverse ether in zero time unless ether be infinitely dense, so that no interval would elapse before one ether particle transferred its motion to the next. But merely the fact that its velocity is millions of times greater than that of light is no evidence of instantaneity. Light itself was regarded in the same way: the assumption of its infinite velocity was tardily relinquished.

A second criticism of the wave theory is that any wave set up by the action of a material particle would have the velocity of light. This can best be considered by an explanation of the fundamental difference assumed to exist between the waves of gravitation and of light. It has been suggested by the writer[1] that gravitation is a longitudinal wave set up in ether by the orbital motion of the electron in the atom, its energy representing the nearly infinitesimal amount which the electron would lose by friction in its rapid displacement of the ether. This is a modern aspect of the wave theories of Guyot, Lamé, and others. The gravitational wave must be assumed different in character from light, because the latter repels instead of attracting matter. Light is believed to be a complex transverse movement of the ether, consisting of two systems of waves having the maximum of one super-imposed on the minimum of the other, and *vice versa*, and caused by the oscillations of the magnetic field and of the inductive force of the electron respectively. The assumption seems reasonable that the electric and magnetic forces are much more complicated motions of the ether than a simple condensational-rarefactional wave: hence the deduction that the latter would possess a greater velocity. According to the opinion of Kelvin,[2] "In order that atoms (or electrons) may take energy from motions of the ether, and that ether may take energy from motions of matter, we must suppose ether to be compressible and dilatable by the forces exerted upon it by atoms. But its resistance to compression is so very great that the velocity of condensational-rarefactional waves in pure ether is practically infinite and their energy nil in comparison with light-waves of equal volume." The energy of gravitation is known to be almost infinitesimal compared with the electrical

(1) *Journal of the Franklin Institute*, August, 1909.
(2) Science Abstracts, No. 2074, 1907.

forces, being about 10^{-43} of the electrostatic forces of electrons, according to Sutherland.[1]

By the electron theory all properties of matter are explained in a general way by electrostatic, magnetic, and inductive forces. Several theories have been advanced to include gravitation in the effects of electrostatic forces. "Like that of the other static force, gravitation, the velocity of electrostatic force may be infinite; and we have as much right to speak about electrostatic rays or waves as we have to speak of rays or waves of gravitational force".[2] The theories of Lorentz and Thomson suppose the attraction of unlike charges to exceed slightly the repulsion of like charges, thus causing a general attraction between uncharged bodies; and also that the repulsion between negative electrons may not quite equal that between positive particles. "The weight of a body on this view depends only on the charges of electcicity it contains. If we suppose an atom of H to contain one positive and one negative charge, the weight of an atom of H would be only twice that of an electron. But its mass is 1,700 that of the electron, hence the acceleration of an electron under gravity would be 850 times that of an atom of H or 850×981; if, on the other hand, the atom of H contained n elementary + and n elementary — charges, the acceleration of the electron taken separately would be $1/n\ 850 \times 981$. . . . With further improvements the effect looked for might be detected in slow kathode rays."[3]

Fessenden's theory of gravitation is based on Newton's suggestion that ether pressure is reduced in the neighborhood of particles. "When we place a dielectric in an electric field, we have a change in the density of the *substance* and a change in the density of the ether. The former gives us Kerr's phenomenon, the latter changes the weight of the condenser."[4] Taking the value of the electrostatic stress at the surface of a corpuscle to be of the order 10^{20}, and having shown the elasticity of the ether to be of the order 6×10^{20}, the ether is assumed to be under enormous stress near the corpuscle. "Inertia is an electromagnetic induction effect due to the corpuscular charge. Gravitation is a secondary effect, the electrostatic intensity due to the

(1) "The Electric Origin of Gravitation and Terrestrial Magnetism," Philosophical Magazine, Dec., 1904.
(2) The Electron Theory (1907), E. E. Fournier d' Albe, p. 193.
(3) Cambridge Phil. Soc., Proc. 15, 1909.
(4) Elec. World & Eng., vol. 36, p. 478.

corpuscular charge causing a change of density in the ether surrounding it, this latter giving the gravitational attraction. . . . Gravitational force is propagated at practically infinite velocity as an expansional wave." Later[1] he calculates the gravitational energy of one of Thomson's corpuscles as 10^{-48} erg, and the velocity of gravitation as 5×10^{36} cm. per second—enormous compared with Arago's calculation.

If gravitation is an action between electrons, our knowledge of it depends on investigation of the dynamics of the electron. If it is electrical in nature, a careful measurement of the electric forces should disclose the source of its energy. Along the least difficult line of research, the testing of weights before and after chemical changes, no reliable data has been obtained to show a loss of weight. C. Zenghelis has shown[2] that the passage of metal vapors through glass accounts for the results of Landolt and others.

These, then, are the main bases of speculation concerning gravitation: an ether pressure, a condensational-rarefactional wave caused by the moving electron, and an electric action between particles. The last two hypotheses seem more tenable than the first; but owing, perhaps, to the fact that they still remain pure speculation, no one of them has been sufficiently analyzed or developed. No vague explaination nor cloudy description on the part of the theorist should be tolerated. Dynamical reasoning based on available facts may eventually lead to the correct theory; analysis, criticism, and experiment are the means to verification.

Saint Paul, Minnesota.

THE ORBIT OF ζ^1 LYRÆ.*

FRANK C. JORDAN

The binary character of the brightest of the five visible components of ζ Lyrae ($\alpha = 18^h\ 41^m$, $\delta = +37°\ 30'$) was discovered from plates taken at the Lick Observatory in 1902, 1903 and 1904, and announced by Dr. H. D. Curtis.† The spectrum is of

(1) *Science*, vol. 12, p. 740.

(2) Zeitschr. Phys. Chem. 65, 3, p. 341.

* Publications of the Allegheny Observatory of the University of Pittsburg, Vol. I, No. 17.

† Lick Observatory Bulletin, No. 70, 1905.

the type I*a*3 in the Vogel classification with numerous well defined metallic lines, among which those of iron predominate.

Sixty-four plates of this star, obtained with the Mellon (single-prism) spectrograph attached to the Keeler Memorial reflector, were measured by the writer and reduced by the method given in Vol. I, No. 2, of these publications. These were all obtained on the Lumiére New Sigma plates, as in a star of this type the fast emulsion gives well measurable lines. The following fifteen lines were used in the determination of the orbit :

λ	*R*	Element	λ	*R*	Element
4012.507	88.650		4233.136	102.649	
4045 996	90.997	Iron	4250.599	103.622	
4063.843	92.215	Iron	4271.613	104.770	
4102.029	94.740	Hydrogen	4290.571	105.785	Iron
4144.039	97.397	Iron	4340.546	108.370	Hydrogen
4198.860	100.687		4352.126	108.951	Magnesium
4215.618	101.655	Iron	4444.197	113.347	
			4481.292	115.013	Magnesium

Column λ contains the wave-lengths adopted for this star which were obtained by making the sum of the residuals for each individual line equal to zero. Column *R* indicates the screw-readings on our measuring engine for zero displacement of the lines.

The exact data for the plates obtained at the Lick Observatory were very kindly furnished by Director Campbell. The observations are as follows :

G. M. T.	h	m	Velocity km.	Phase. days
1902 July 15,	23	21	+21.8	0.11
1903 July 21,	18	03	−27.7	1.09
1904 May 15,	19	07	— 6.4	3.43
1904 Aug. 1,	20	10	+21.6	4.07

A comparison of these results* with our own gives a period of 4.29991 days, probably correct to the fourth decimal place. As this could not be improved in accuracy by a discussion of our own plates extending over a period of only 102 days, it was adopted as the definitive period. With this period phases were computed, and the observations grouped into seventeen normal places. A preliminary investigation showed that the observations seemed to be best satisfied by a circular orbit with the following elements :

$P = 4.29991$ days
$K = 50.50$ km.
$\gamma = -26.50$ km.
$T = 1908$, June 16.716 G. M. T.

Preliminary elements.

T represents the time of maximum positive velocity, and is the

* For knowledge of the table of observations and the table of normal places, reference should be made to the full paper.

point from which the phases were computed. With these elements an ephemeris was computed and differential coefficients derived for the normal places in accordance with the notation given in Vol. I, No. 6 of these publications.

The following normal equations result:

$$\begin{array}{rrrr} \Gamma & \kappa & \tau & \\ 9.2 & -6.294 & +0.531 & =+4.90 \\ & +4.755 & +0.826 & =+3.68 \\ & & +4.445 & =+2.82 \end{array}$$

The solution of these equations gives corrections to the preliminary elements as follows:

$\delta K = +0.736$ km. $\quad \delta T = +0.006$ days. $\quad \delta\gamma = +0.531$ km.

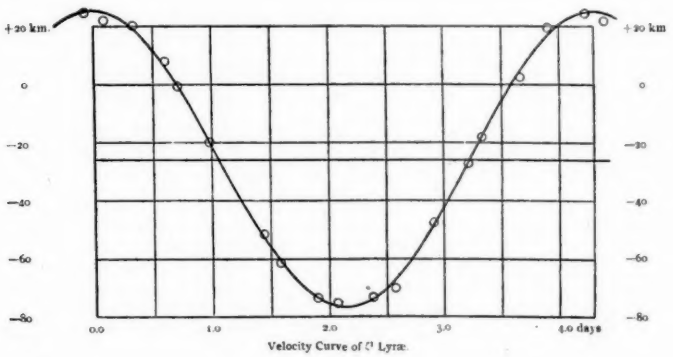
The final elements with their probable errors are therefore:

$P = 4.29991$ days		Final elements.
$\mu = 83°.70439$		
$e = 0.00$		
$T = 1908$ June 16.722 G. M. T.	± 0.005 days	
$K = 51.24$ km.	± 0.35 km.	
$\gamma = -25.97$ km.	± 0.25 km.	
$a \sin i = 3{,}030{,}000$ km.		

The considerable negative value of γ is due almost entirely to the motion of the solar system in space, as the location of ζ Lyrae is very near the solar apex, toward which our system is moving at about 20 km. per second.

In this star no trace of a secondary spectrum could be found on any of the plates.

In column (8) of the table of observations, the residuals are scaled from the final curve. From these residuals the probable error of a single plate is found to be ± 2.04 km. My thanks are due Director Schlesinger for suggestions in the discussion of this orbit.

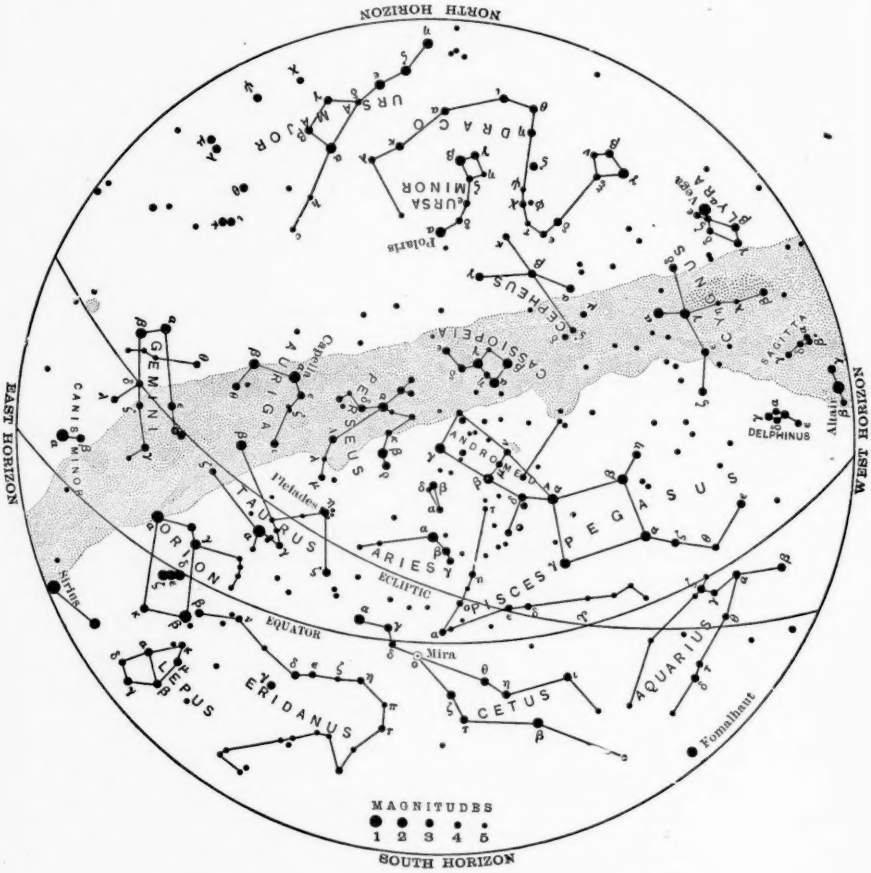


Velocity Curve of ζ Lyræ

PLANET NOTES FOR DECEMBER, 1909.

Mercury will be invisible this month, being at superior conjunction on December 2.

Venus will be at greatest elongation, 47° 18′ east from the Sun on Dec. 2.



THE CONSTELLATIONS AT 9:00 P. M., DECEMBER 1, 1909.

The planet during this elongation has been so far south of the equator that it has not been well situated for study by northern observers. In the southern hemisphere conditions are much better.

Mars during December will move northeast and will come into conjunction with Saturn on the last day of the month. Mars will then be 3° 12′ north of

Saturn. The apparent diameter of Mars will decrease during the month from 14″ to 10″.

Jupiter is now visible in the morning, being visible toward the east after two o'clock.

Saturn is visible in the evening not far from Mars in the constellation Pisces. The rings of Saturn are plainly seen and make an angle of about 10°.5 with the line of sight from Earth.

Uranus is too nearly in the direction of the Sun to be seen. It will be in conjunction with Mercury on the morning of December 28.

Neptune is in Gemini, and may be studied with a telescope during the latter half of the night.

A Partial Eclipse of the Sun will occur on December 12, but will be visible only in the antartic regions and the islands in the South Pacific and South Atlantic oceans.

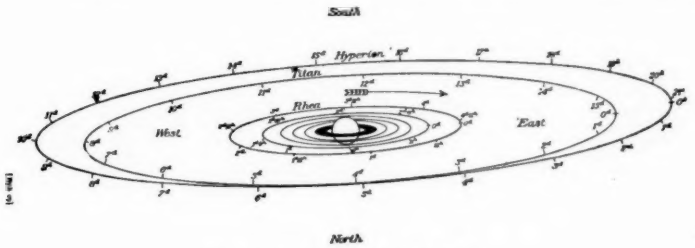
Occultations visible at Washington.

Date 1909	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration. h m
Dec. 2	η Leonis	3.6	16 05	129	17 33	288	1 28
22	31 Arietis	5.7	7 18	3	8 04	288	0 46
23	26 B. Tauri	6.4	8 08	345	8 27	315	0 19
24	224 B. Tauri	6.1	2 51	12	3 16	309	0 25
25	132 Tauri	5.0	15 07	154	15 36	207	0 29
26	37 Geminorum	5.7	16 40	89	17 40	290	1 00

Saturn's Satellites.

I. Mimas. Period $0^d\ 22^h.6$.

	h		h		h		h
Dec. 1	9.7 E	Dec. 9	10.0 W	Dec. 17	10.2 E	Dec. 25	10.5 W
2	8.3 E	10	8.6 W	18	8.9 E	26	9.1 W
3	6.9 E	11	7.2 W	19	7.5 E	27	7.7 W
4	5.5 E	12	5.8 W	20	6.1 E	28	6.3 W
8	11.3 W	16	11.6 E	21	4.7 E	29	4.9 W



II. Enceladus. Period $1^d\ 8^h.9$.

Dec. 1	8.2 E	Dec. 9	13.5 E	Dec. 17	18.8 E	Dec. 26	0.1 E
2	17.1 E	10	22.4 E	19	3.7 E	27	9.0 E
4	1.9 E	12	7.2 E	20	12.6 E	28	17.9 E
5	10.8 E	13	16.1 E	21	21.4 E	30	2.8 E
6	19.7 E	15	0.9 E	23	6.3 E	31	11.7 E
8	4.6 E	16	9.7 E	24	15.2 E		

Saturn's Satellites.—Continued.

III. Tethys. Period $1^d\ 21^h.3$.

		h			h			h			h
Dec.	2	1.8 E	Dec.	9	15.0 E	Dec.	17	4.2 E	Dec.	24	17.5 E
	3	23.1 E		11	12.3 E		19	1.5 E		26	14.8 E
	5	20.4 E		13	9.6 E		20	22.8 E		28	12.1 E
	7	17.7 E		15	6.9 E		22	20.1 E		30	9.4 E

IV. Dione. Period $2^d\ 17^h.7$.

Dec.	1	19.6 E	Dec.	10	0.6 E	Dec.	18	5.7 E	Dec.	26	10.7 E
	4	13.3 E		12	18.3 E		20	23.4 E		29	4.4 E
	7	6.9 E		15	12.0 E		23	17.1 E		31	22.2 E

V. Rhea. Period $4^d\ 12^h.5$.

Dec.	1	21.1 E	Dec.	10	21.9 E	Dec.	19	22.7 E	Dec.	28	23.6 E
	6	9.5 E		15	10.3 E		24	11.1 E			

VI. Titan. Period $15^d\ 23^h.3$.

Dec.	2	20.1 S	Dec.	11	2.3 I	Dec.	18	18.6 S	Dec.	27	1.0 I
	6	23.2 E		14	22.5 W		22	22.7 E		30	21.3 W

VII. Hyperion. Period $21^d\ 7^h.6$.

Dec.		2.3 W	Dec.		13.3 E	Dec.		23.5 W	Dec.		28.3 S
		7.1 S			19.0 I						

VIII. Iapetus. Period $79^d\ 22^h.1$.

Oct.		18.4 E	Nov.		7.5 I	Nov.		27.2 W	Dec.		16.4 S

COMET NOTES.

Halley's Comet.—A letter has been received at this observatory from Professor E. B. Frost, director of the Yerkes Observatory, stating that Halley's comet was observed visually by Professor E. E. Barnard on Sept. $24^d\ 20^h\ 22^m\ 21^s$, Gr. M. T. in

App. R. A. $6^h\ 18^m\ 56^s.72$
App. Dec. $+17^\circ\ 6'\ 11''.2$

Comet followed comp. star $0^m\ 19^s.03$ by eight direct measures.
Comet north of comp. star $0'\ 39''.4$ by nine direct measures.

The comparison star was Berlin A. G. 2122.

"The comet was considerably brighter than on the 17th; estimated, as 15th magnitude; measured diameter 11″; indefinite condensation almost amounting to a small nucleus; no definite boundary."

Astronomical Bulletin, No. 359,
Harvard College Observatory,
Cambridge, Mass., Sept. 27, 1909.

Ephemeris of Halley's Comet.—A letter has been received at this observatory from Father G. M. Searle, C. S. P. of New York, giving the following results of his calculations on Halley's comet. Using the observations made at the Lick Observatory on Sept. 12, 13, 14, and the elements given by Cowell and Crommelin in the *Mon. Not.* for Mar. 1908, he finds corrected T=Apr. $18^d.63$, 1910; $e = 0.96719$; $q = 0.58870$.

EPHEMERIS.

G. M. T.	R.A. 1909.9	Decl. 1909.9	log Δ	Br. Sept. 14 = 1
	h m s	° ′		
1909 Sept. 22.0	6 19 3	+17 7.4	0.510	1.4
26.0	6 18 47	17 5.7	0.494	1.7
30.0	6 18 9	17 4.2	0.477	2.0
Oct. 4.0	6 17 4	17 2.7	0.459	2.3
8.0	6 15 30	17 1.2	0.441	2.7
12.0	6 13 24	16 59.8	0.421	3.1
16.0	6 10 40	16 58.6	0.401	3.6
20.0	6 7 14	16 57.3	0.381	4.2
24.0	6 6 1	16 56.2	0.360	4.8
28.0	5 57 55	+16 54.9	0.338	5.5

"The nearest approach of the comet will be on May 19, at a distance about 0.14. On May 18^d.14 G. M. T., the Earth and comet will be in heliocentric conjunction in longitude; the longitude being 236° 48′. The heliocentric latitude of the comet would then be −7′. There would be no actual transit of the comet over the Sun's disk according to these elements, but a slight change in them might produce one. At any rate, it seems highly probable that we shall on May 18, be inside the tail."

Astronomical Bulletin, No. 361,
Harvard College Observatory,
Cambridge, Mass., Sept. 31, 1909.

Corrected Ephemeris of Halley's Comet.—In *A. N.* 4359 Mr. A. C. D. Crommelin of the Greenwich Observatory gives a corrected ephemeris of Halley's comet on the supposition that the time of perihelion passage will be April 20.0. The following is the portion for the remainder of this year.

Berlin m. t. 1909	R.A. 1910.0	Decl. 1910.0	log r	log Δ	Magnitude A	Magnitude B
	h m s	° ′			m	m
Oct. 27.4	5 59 07	+16 54	0.4608	0.3447	14.6	14.2
Nov. 1.4	51 40	16 52				
6.4	42 33	16 49	0.4420	0.2906	14.3	13.8
11.4	31 32	16 44				
16.4	18 33	16 38	0.4219	0.2361	13.9	13.3
21.4	5 03 23	16 26				
26.4	4 46 13	16 13	0.4005	0.1870	13.5	12.8
Dec. 1.4	26 56	15 52				
6.4	4 06 13	15 23	0.3775	0.1505	13.2	12.4
11.4	3 44 24	14 45				
16.4	22 19	14 04	0.3527	0.1340	13.0	12.0
21.4	3 0 34	13 18				
26.4	2 40 11	+12 28	0.3259	0.1381	12.9	11.8

The magnitudes have been deduced on the assumptions

(A) that the brightness varies as $\frac{1}{r^2\Delta^2}$

(B) that it varies as $\frac{1}{r^4\Delta^2}$, that is that the physical brightness varies as $\frac{1}{r^2}$; the constant in each case being deduced from Dr. Wolf's observed magnitude 16.0 on Sept. 11.

Halley's Comet.—The following information is taken from letters to this observatory.

1. Professor Barnard, of the Yerkes Observatory, observed Halley's comet on 1909, Sept. $26^d\ 21^h\ 21^m\ 51^s$ G. M. T., in App. R.A. $6^h\ 10^m\ 44^s.44$ and App. Decl. $+17°\ 5'\ 21''.1$.
2. Father Searle, C. S. P. of New York, using Barnard's observation of of Sept. 26, finds the following revised values of the elements T, e, q, of Halley's comet.
   $T = 1910$, Apr. $18^d.63$ G. M. T., $e = 0.967195$, $q = 0.58863$. His former values, given in Harvard Bulletin 361, were $T = 1910$, Apr. $18^d.63$ G. M. T., $e = 0.967191$, $q = 0.58870$.
3. Professor W. W. Campbell, of the Lick Observatory, writes, for "a little" (Harvard Bulletin 356, sixth line) read "little a."

Astronomical Bulletin, No. 362,
Harvard College Observatory,
Cambridge, Mass., Oct. 13, 1909.

Phoebe.—A letter received at this observatory from the Rev. J. H. Metcalf of Taunton, Mass., states that he has photographed Phoebe, the ninth satellite of Saturn, on three nights, in the positions given below.

G. M. T.				R. A.			Decl.		
	d	h	m	s			°	′	
1909 Oct.	9	14	36	45	1	19	57.9	+5	28.1
	10	14	12	0	1	19	41.2	+5	26.5
	12	14	16	30	1	19	7.8	+5	23.2

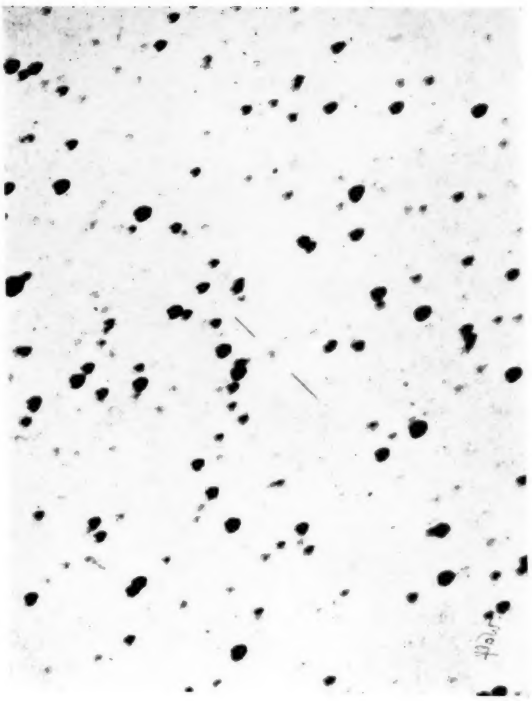
The photographs were taken with the 12-inch photographic doublet constructed by him.

Astronomical Bulletin, No. 363,
Harvard College Observatory,
Cambridge, Mass., Oct. 14, 1909.

Ephemeris of Winnecke's Periodic Comet.—The following is given in *A. N.* 4360, and shows that Winnecke's comet has already passed its point of nearest approach to the Earth, and is beginning to recede. It seems somewhat doubtful whether the comet will be found at this apparition.

Berlin M. T. 1909		α app.			δ app.			log r	log Δ	$1 : r^2\Delta^2$
		h	m	s	°	′				
Nov.	1	17	17	41	−27	45.1		0.01296	0.18376	0.404
	2		22	55	28	4.9				
	3		28	10	28	23.9				
	4		33	27	28	42.1				
	5		38	44	28	59.5		0.02139	0.18617	0.384
	6		44	3	29	16.0				
	7		49	22	29	31.7				
	8	17	54	42	29	46.6				
	9	18	0	3	30	0.6		0.03067	0.18964	0.363
	10		5	25	30	13.8				
	11		10	46	30	26.1				
	12		16	8	30	37.5				
	13		21	30	30	48.1		0.04063	0.19414	0.339
	14		26	51	30	57.8				
	15		32	13	31	6.6				
	16	18	37	34	−31	14.5				

PLATE X



M. Wolf Heidelberg

HALLEY'S COMET
1909 September 11.7
10 x enlarged 1mm=7 in. Zeiss-Reflecktor

Berlin M. T. 1909	α app. h m s	δ app. ° ′	log r	log Δ	$1:r^2\Delta^2$
Nov. 17	18 42 54	−31 21.6	0.05114	0.19963	0.315
18	48 14	31 27.8			
19	53 32	31 33.1			
20	58 50	31 37.6			
21	18 4 6	31 41.3	0.06207	0.20605	0.291
22	19 9 21	31 44.1			
23	14 35	31 46.1			
24	19 47	31 47.3			
25	24 57	31 47.8	0.07330	0.21334	0.267
26	30 6	31 47.4			
27	35 12	31 46.3			
28	40 17	31 44.5			
29	45 19	31 41.9	0.08473	0.22141	0.244
30	50 19	31 38.6			
Dec. 1	19 55 17	31 34.6			
2	20 0 12	31 29.9			
3	5 5	31 24.6	0.09626	0.23020	0.222
4	9 55	31 18.7			
5	14 42	31 12.1			
6	19 27	31 5.0			
7	24 9	30 57.2	0.10784	0.23959	0.202
8	28 49	30 48.9			
9	33 25	30 40.1			
10	37 59	30 30.8			
11	42 30	30 20.9	0.11939	0.24951	0.183
12	46 58	30 10.6			
13	51 23	29 59.8			
14	20 55 45	29 48.6			
15	21 0 4	29 37.0	0.13087	0.25986	0.165
16	4 20	39 25.0			
17	8 34	29 12.6			
18	12 44	28 59.8			
19	16 51	28 46.7	0.14223	0.14223	0.149
20	20 56	28 33.3			
21	24 57	28 19.5			
22	28 56	28 5.5			
23	32 51	27 51.2	0.15345	0.28150	0.135
24	21 36 45	−27 36.6			

VARIABLE STARS.

Algol Variable 37.1907 Cassiopeiae.—In *A. N.* 4352 Mr. W. Munch of Potsdam, Germany, gives a number of observations of variable stars. Among them he gives observations of the star 37.1907 Cassiopeiae, which include three minima: 1908 Oct. 10, Oct. 20 and Nov. 20. These would indicate that the period may possibly be about ten days. The range of brightness appears to be between the magnitudes 8.0 and 8.5. The position of the star for 1900 is

$$\alpha = 2^h\ 37^m\ 38^s,\quad \delta = +65^\circ\ 18'.6.$$

Variable 42.1907 Ursae Majoris.—For this variable Mr. Munch finds a period of about 8.8 days, and a continuous variation, the light curve being very symmetrical, ranging between magnitudes 6.7 and 7.2. The position for 1900 is

$$\alpha = 11^h\ 22^m\ 22^s,\quad \delta = +45^\circ\ 44'.2.$$

Variable 78.1907 Aurigae.—According to Mr. Munch, this star is possibly of the β Lyrae type. The period of $16^h.0$ determined by Enebo seems to fit the observations quite well.

Minimum = 2418046.37 Gr. m. t. $+0^d.666364$ E.

The range of variation is between magnitudes 8.1 and 9.4. The position of the star for 1900 is

$$\alpha = 5^h\ 2^m\ 47^s, \quad \delta = +39^\circ\ 27'.7.$$

Variable 147.1907 Arietis.—Mr. Munch finds for this star a range of about 0.4 magnitude (8.5-8.9) and possible period of about eight days. A maximum occurred about Sept. 21, 1908. The position of the star for 1909 is

$$\alpha = 2^h\ 9^m.6 \quad \delta = +11^\circ\ 46'.$$

Variable 11.1908 Orionis.—This star Mr. Munch finds to be of the δ Cephei type with a period of about 7.56 days. The increase of light after minimum occupies two days while the decline requires 5.5 days. Range of magnitude 7.8-8.5. Approximate elements:

Maximum = 2418258.2 Gr. m. t. $+ 7^d.56$ E.

The place of the star for 1900 is $\alpha = 6^h\ 16^m\ 31^s$, $\delta = +14^\circ\ 43'.5$.

Variable 6.1909 Ursae Majoris.—In *A. N.* 4355 Professor Max Wolf gives observed magnitudes of this variable as

1909 Feb 21 $10^m.8$ May 9 $11^m.2$ Aug. 7 $14^m.5$

This star is in the great spiral nebula Messier 101, and is doubtless a long period variable.

New Variable 22.1909 Pegasi.—This was discovered by Mme. L. Ceraski on the Moscow photographs. Six plates of the region give the following magnitudes for this star:

1905 Sept.	4	$<10^m$ (invis)	1909 Aug.	22	$9\frac{1}{2}^m$
	6	$<10\frac{1}{2}$ (invis)	Sept.	10	$9\frac{1}{2}$
1909 Aug.	19	$9\frac{1}{2}$		11	$9\frac{1}{2}$

Its position for 1900.0 is $\alpha = 21^h\ 17^m\ 58^s$, $\delta = +21^\circ\ 34'$.

RU Cassiopeiae.—In *A. N.* 4355 Mr. G. Hornig, a student at Breslau, gives observations made during 1908 and 1909 which include four minima and three maxima of RU Cassiopeiae. From these he derives the elements

Maximum = 2418387 $+75^d.5$.

The minima are half-way between the maxima.

TT Cygni.—In *A. N.* 4358 Mr. S. Beljawsky gives a series of observations of TT Cygni made during the years 1907-1909, which indicate a period of about 400 days and a range of variation between magnitudes 7.5 and 8.3.

Twenty New Variable Stars.—In Circular No. 151 of Harvard College Observatory is given a list of twenty new variables discovered by Miss Cannon on the plates for the Harvard map, No. 49. Seventeen known variables were found on the same plates. The center of the map is at R.A. $9^h\ 00^m$, Decl. -60°.

Harvard Number	Constellation	DM.	R.A. 1900.0 h m s	Decl. 1900.0 ° ′	Magnitude
3189	Volans	−69° 756	7 37 57.5	−69 18.9	10.0—10.9
3190	Vela	−43 4474	8 33 34.7	−43 46.0	7.5— 8.6
3191	Vela	−46 4498	8 40 21.1	−47 02.6	8.8— 9.8
3192	Vela	−45 4490	8 41 31.9	−45 58.6	8.5— 9.3
3193	Vela	−50 3533	8 41 50.0	−50 11.9	9.7—10.5
3194	Vela	−50 3870	8 05 03.2	−51 02.0	8.1— 9.0
3195	Vela	−49 4237	9 10 58.1	−49 21.5	9.8—10.6
3196	Vela	−50 4012	9 15 38.6	−50 08.6	9.9—11.9
3197	Vela	−48 4613	9 16 52.6	−49 06.2	8.5—11.0
3198	Vela	−50 4168	9 24 07.4	−50 38.0	8.8—10.5
3199	Vela	−49 4469	9 28 08.5	−49 12.8	9.2—10.0
3200	Carina	−71 873	9 44 39.7	−71 44.8	9.3—10.2
3201	Carina		9 45 18	−56 04.2	10.0<13.5
3202	Vela	−54 3079	10 00 46.3	−54 43.0	10.0—10.8
3203	Vela	−52 3245	10 03 50.9	−52 46.2	9.1— 9.9
3204	Carina		10 10 11	−60 23.3	10.0<15.5
3205	Vela	−54 3497	10 16 55.9	−54 49.1	8.0—10.0
3206	Carina	−60 1856	10 17 58.0	−60 34.1	9.0— 9.7
3207	Carina	−57 3238	10 23 16.7	−57 45.9	9.3<12
3208	Carina	−56 3777	10 42 07.4	−57 01.3	8.3—10.0

Notes.—3189 probably of Algol type. 3190 period probably short. 3193 period probably short. 3194 period probably short. 3204 long period; maximum 2410168 +231 E. 3207 period probably long.

Variable Star—Tauri, 054319.—The variable star Harvard 3089 whose position for 1900 is R. A. = $5^h\ 43^m\ 12^s$, Decl. = +19° 2′.0, and which follows the Durchmusterung star, +19° 1081, about 3^s and is south 0′.2, was announced to be variable by Miss Cannon on July 13, 1908, in H. C. 140. It is also stated in that circular, "The variation is large, but it appears uncertain whether this star belongs to Class II, variables of long period, or is peculiar and resembles R Coronae Borealis." The latter view is confirmed and measures of this object have been made by Miss C. E. Burns on 408 Harvard photographs, taken between December 16, 1885 and December 14, 1908. During this period of time, only four minima are shown on the photographs. The first of these minima occurred in February, 1891, but its duration has not been determined, since there is no photograph between February 22, 1891, when the star was invisible and fainter than magnitude 12.4, and November 13, 1891, when it was magnitude 10.3, full brightness. The next minimum lasted from December, 1898 to December, 1899, the third from September, 1904 to August, 1905, and the fourth, which commenced in November, 1908, is still in progress. No trace of the star was visible on a plate taken September 6, 1909, and showing stars of the magnitude 12.5. The photographic magnitude at maximum is about 10.3. The light is often nearly constant for several years. Thus, 112 photographs well distributed between February 15, 1900 and April 12, 1904, show the star to be at or near maximum brightness. The minimum magnitude is evidently very faint. No trace of the star is seen on two good plates taken with the Bruce photographic telescope and showing stars as faint as the magnitude 15 The star was looked for by Miss Cannon, but was not visible in the 6-inch telescope of this observatory in December, 1908, January, February and March, 1909. It was not seen by Mr. Leon Campbell with the 24-inch Reflector on April 10 and April 22, 1909, and was probably fainter than the magnitude 14 on these dates.

Extract from Harvard Circular, No. 151.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

SY Androm.

	d	h
Dec.	27	12

U Cephei

	d	h
Dec.	1	2
	3	14
	6	2
	8	14
	11	2
	13	14
	16	1
	18	13
	21	1
	23	13
	26	1
	28	13
	30	0

Z Persei

	d	h
Dec.	3	9
	6	10
	9	11
	12	13
	15	14
	18	15
	21	17
	24	18
	27	20
	30	21

RY Persei

	d	h
Dec.	1	7
	8	4
	15	1
	21	22
	28	18

RZ Cassiop.

	d	h
Dec.	1	17
	2	22
	4	3
	5	7
	6	12
	7	17
	8	21
	10	2
	11	7
	12	11
	13	16
	14	21
	16	1
	17	6
	18	11
	19	15
	20	20
	22	1
	23	6
	24	10
	25	15

RZ Cassiop.

	d	h
Dec.	26	20
	28	0
	29	5
	30	10
	31	14

RX Cephei

	d	h
Dec.	1	5

ST Persei

	d	h
Dec.	2	20
	5	19
	8	3
	10	18
	13	10
	16	2
	18	17
	21	9
	24	0
	26	16
	29	7
	31	23

B Persei

	d	h
Dec.	1	22
	4	19
	7	16
	10	13
	13	9
	16	6
	19	3
	22	0
	24	21
	27	18
	30	14

RT Persei

	d	h
Dec.	1	6
	2	3
	2	23
	3	20
	4	16
	5	12
	6	9
	7	5
	8	2
	8	22
	9	18
	10	15
	11	11
	12	8
	13	4
	14	0
	14	21
	15	17
	16	13
	17	10
	18	6
	19	3
	19	23

RT Persei

	d	h
Dec.	20	19
	21	16
	22	12
	23	9
	24	5
	25	1
	25	22
	26	18
	27	14
	28	11
	29	7
	30	4
	31	0
	31	20

λ Tauri

	d	h
Dec.	3	20
	7	19
	11	18
	15	16
	19	15
	23	14
	27	13
	31	12

RW Tauri

	d	h
Dec.	5	13
	8	7
	11	2
	13	20
	16	15
	19	9
	22	4
	24	22
	27	17
	30	11

RV Persei

	d	h
Dec.	2	8
	4	8
	6	7
	8	6
	10	6
	12	5
	14	5
	16	4
	18	3
	20	3
	22	2
	24	1
	26	1
	28	0
	30	23

RW Persei

	d	h
Dec.	4	10
	17	15
	30	20

RS Cephei

	d	h
Dec.	2	7
	14	17
	27	3

RY Aurigæ

	d	h
Dec.	1	22
	4	15
	7	8
	10	2
	12	19
	15	13
	18	6
	21	0
	23	17
	26	11
	29	4
	31	22

RZ Aurigæ

	d	h
Dec.	2	15
	5	15
	8	16
	11	16
	14	16
	17	17
	20	17
	23	18
	26	18
	29	18

RW Geminorum

	d	h
Dec.	2	16
	5	13
	8	9
	11	6
	14	3
	17	0
	19	21
	22	17
	25	14
	28	11
	31	8

U Columbæ

	d	h
Dec.	3	5
	6	0
	8	19
	11	15
	14	10
	17	5
	20	0
	22	19
	25	15
	28	10
	31	5

RW Monoc.

	d	h
Dec.	2	15
	4	13

RW Monoc.

	d	h
Dec.	6	10
	8	8
	10	6
	12	4
	14	1
	15	23
	17	21
	19	19
	21	16
	23	14
	25	12
	27	10
	29	8
	31	5

RX Geminorum

	d	h
Dec.	12	17
	24	22

RU Monoc.

	d	h
Dec.	1	10
	2	8
	3	5
	4	3
	5	0
	5	22
	6	19
	7	17
	8	14
	9	12
	10	9
	11	7
	12	4
	13	2
	13	23
	14	21
	15	18
	16	16
	17	13
	18	11
	19	8
	20	6
	21	3
	22	1
	22	22
	23	20
	24	17
	25	15
	26	12
	27	10
	28	7
	29	5
	30	2
	31	0
	31	21

RY Geminorum

	d	h
Dec.	6	18
	16	1
	25	9

Minima of Variable Stars of the Algol Type.—Continued.

R Canis Maj.

	d	
Dec.	1	3
	2	6
	3	9
	4	12
	5	16
	6	19
	7	22
	9	1
	10	5
	11	8
	12	11
	13	14
	14	18
	15	19
	17	0
	18	4
	19	7
	20	10
	21	13
	22	17
	23	18
	24	23
	26	2
	27	6
	28	9
	29	12
	30	15
	31	19

Y Camelop.

Dec.	2	9
	5	16
	9	0
	12	7
	15	14
	18	22
	22	5
	25	12
	28	20

RR Puppis

Dec.	7	6
	13	17
	20	3
	26	13

V Puppis

Dec.	3	7
	4	18
	6	5
	7	16
	9	3
	10	14
	12	2
	13	12
	14	23
	16	10
	17	21
	19	7
	20	18
	22	5

V Puppis

	d	h
Dec.	23	16
	25	3
	26	14
	28	1
	29	12
	30	23

X Carinæ

Dec.	1	13
	2	15
	3	17
	4	19
	5	21
	6	23
	8	1
	9	3
	10	5
	11	7
	12	9
	13	11
	14	13
	15	15
	16	17
	17	18
	18	20
	19	22
	21	0
	22	2
	23	4
	24	6
	25	8
	26	10
	27	12
	28	14
	29	16
	30	18
	31	20

S Cancri

Dec.	10	10
	19	22
	29	10

Y Leonis

Dec.	1	22
	3	15
	5	7
	7	0
	8	16
	10	9
	12	1
	13	18
	15	10
	17	2
	18	19
	20	12
	22	4
	23	20
	25	13
	27	5
	28	22
	30	14

S Velorum

	d	h
Dec.	5	14
	11	12
	17	11
	23	9
	29	7

RR Velorum

Dec.	2	2
	3	23
	5	19
	7	16
	9	12
	11	9
	13	5
	15	2
	16	22
	18	19
	20	15
	22	12
	24	8
	26	5
	28	1
	29	22
	31	18

SS Cancri

Dec.	1	18
	5	2
	8	9
	11	16
	14	23
	18	6
	21	14
	24	21
	28	4
	31	11

RW Urs. Maj.

Dec.	2	1
	9	9
	16	17
	24	1
	31	9

Z Draconis

Dec.	1	11
	2	20
	4	4
	5	13
	6	22
	8	6
	9	15
	10	23
	12	8
	13	16
	15	1
	16	9
	17	18
	19	3
	20	11
	21	20

Z Draconis

	d	h
Dec.	23	4
	24	13
	25	22
	27	6
	28	15
	29	23
	31	8

SS Centauri

Dec.	2	15
	5	2
	7	14
	10	1
	12	13
	15	0
	17	12
	19	23
	22	11
	24	22
	27	10
	29	21

δ Libræ

Dec.	1	4
	3	12
	5	20
	8	4
	10	11
	12	19
	15	3
	17	11
	19	19
	22	3
	24	11
	26	18
	29	2
	31	10

U Coronæ

Dec.	2	6
	5	17
	9	4
	12	15
	16	2
	19	13
	23	0
	26	10
	29	21

RX Draconis

Dec.	1	14
	3	12
	5	9
	7	6
	9	4
	11	1
	12	23
	14	20
	16	18
	18	15
	20	13
	22	10

RX Draconis

	d	h
Dec.	24	8
	26	5
	28	3
	30	0
	31	21

RV Lyræ

Dec.	4	9
	7	23
	11	14
	15	4
	18	18
	22	9
	25	23
	29	14

U Sagittae

Dec.	3	22
	7	7
	10	16
	14	2
	17	11
	20	20
	24	5
	27	14
	30	23

SY Cygni

Dec.	3	22
	9	22
	15	23
	21	23
	27	23

WW Cygni

Dec.	2	12
	5	19
	9	3
	12	10
	15	18
	19	2
	22	9
	25	17
	29	1

SW Cygni

Dec.	1	1
	5	14
	10	4
	14	18
	19	7
	23	21
	28	11

VW Cygni

Dec.	9	4
	17	14
	26	0

UW Cygni

Dec.	3	13
	7	0
	10	10

Minima of Variable Stars of the Algol Type.—Continued.

UW Cygni		W Delphini		VV Cygni		VV Cygni		143.1907 Andr.	
d	h	d	h	d	h	d	h	d	h
Dec. 13	21	Dec. 23	4	Dec. 1	18	Dec. 19	12	Dec. 1	3
17	8	27	23	3	6	20	23	3	21
20	19			4	17	22	10	6	16
24	6			6	4	23	22	9	10
27	16	RR Delphini		7	16	25	9	12	4
31	3	Dec. 2	8	9	3	26	21	14	23
		6	22	10	15	28	8	17	17
W Delphini		11	13	12	2	29	20	20	11
Dec. 3	22	16	3	13	14	31	7	23	6
8	18	20	17	15	1			26	0
13	13	25	8	16	13	UZ Cygni		28	18
18	8	29	22	18	0	Dec. 13	23	31	13

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SY Cassiop.		ζ Geminorum		T Crucis		RZ Centauri		R Triang. Austr.	
d	h	d	h	d	h	d	h	d	h
Dec. 3	6	(−5 0)		(−2 2)		Dec. 13	17	Dec. 14	2
7	8	Dec. 10	23	Dec. 2	12	14	15	17	11
11	10	21	3	9	6	15	14	20	21
15	11	31	7	15	23	16	13	24	6
19	13	RU Camelop.		22	17	17	11	25	15
23	15	(−9 12)		29	11	18	10	31	1
27	16	Dec. 3	10			19	8	S Triang. Austr.	
31	18	25	17	R Crucis		20	7	(−2 2)	
		V Carinæ		(−1 10)		21	5	Dec. 5	13
RW Cassiop.		(−2 4)		Dec. 3	15	22	4	11	21
(−5 19)		Dec. 1	3	9	11	23	2	18	5
Dec. 5	2	7	20	15	7	24	1	24	12
19	22	14	13	21	2	24	23	30	20
		21	5	26	22	25	22		
RX Aurigæ		27	22	S Crucis		26	20	S Normæ	
(−4 0)				(−1 12)		27	19	(−4 10)	
Dec. 11	17	T Velorum		Dec. 1	20	28	17	Dec. 6	15
23	8	(−1 10)		6	12	29	16	16	9
		Dec. 5	0	11	5	30	14	26	3
Y Aurigæ		9	15	15	21	31	13		
(−0 18)		14	7	20	14			RV Scorpii	
Dec. 1	22	18	22	25	7	W Virginis		(−1 10)	
5	18	23	13	29	23	(−8 5)		Dec. 4	4
9	15	28	5	RZ Centauri		Dec. 8	12	10	6
13	12	W Carinæ		Dec. 1	12	25	18	16	7
17	8	(−1 0)		2	11			22	9
21	5	Dec. 4	3	3	9	V Centauri		28	10
25	1	8	12	4	8	(−1 11)			
28	22	12	21	5	6	Dec. 5	1	RV Ophiuchi	
		17	5	6	5	10	12	Minimum	
T Monoc.		21	14	7	3	16	0	Dec. 2	18
(−9 23)		25	23	8	2	21	12	6	11
Dec. 14	17	30	8	9	0	27	0	10	3
		S Muscæ		9	23			13	20
W Geminorum		(−3 11)		10	21	R Triang. Austr.		17	12
(−2 2)		Dec. 9	13	11	20	(−1 0)		21	5
Dec. 8	6	19	5	12	18	Dec. 3	22	24	21
16	4	28	21			7	7	28	13
24	1					10	17		
31	23								

Maxima of Variable Stars of Short Period not of the Algol Type.-Con

X Sagittarii

	d	h
	(−2	21.5)
Dec.	4	1
	11	1
	18	1
	25	1

Y Ophiuchi

	(−6	5)
Dec.	17	12

W Sagittarii

	(−3	0)
Dec.	5	5
	12	20
	20	10
	28	0

Y Sagittarii

	(−2	2)
Dec.	9	11
	15	5
	21	0
	26	19

U Sagittarii

	(−2	23)
Dec.	10	11
	17	5
	23	23
	30	17

β Lyræ

	(−3	7)
	(−3	2)
Dec.	1	16
	7	21
	14	13
	20	20
	27	12

κ Pavonis

	d	h
	(−4	7)
Dec.	6	21
	15	23
	25	1

U Aquilæ

	(−2	4)
Dec.	7	3
	14	3
	21	4
	28	5

V Vulpeculæ

	(−2	3)
Dec.	4	4
	12	3
	20	3
	28	2

SW Cygni

	(−1	7)
Dec.	3	12
	7	8
	11	5
	15	1
	18	21
	22	18
	26	14
	30	10

η Aquilae

	(−2	6)
Dec.	4	1
	11	5

η Aquilae

	d	h
	18	10
	25	14

S Sagittae

	(−3	10)
Dec.	8	6
	16	15
	25	1

X Vulpeculae

	(−2	1)
Dec.	4	18
	11	2
	17	9
	23	17
	30	0

X Cygni

	(−6	19)
Dec.	4	20
	21	5

T Vulpeculae

	(−1	10)
Dec.	4	4
	8	14
	13	1
	17	11
	21	21
	26	8
	30	19

TX Cygni

Dec.	7	1
	21	19

VY Cygni

	d	h
	(−2	14)
Dec.	1	7
	9	3
	17	0
	24	20

VZ Cygni

	(−2	12)
	(−3	6)
Dec.	4	14
	9	14
	14	8
	19	8
	24	1
	29	1

Y Lacertae

	(−1	10)
Dec.	1	20
	6	3
	10	11
	14	19
	19	2
	23	10
	27	17

δ Cephei

Dec.	4	23
	10	8
	15	17
	21	1
	26	8
	31	19

V Lacertae

	d	h
	(−1	16)
Dec.	3	21
	8	21
	13	20
	18	21
	23	20
	28	19

X Lacertae

Dec.	1	17
	7	4
	12	14
	18	1
	23	11
	28	22

SW Cassiop.

Dec.	4	12
	10	1
	15	14
	21	3
	26	16

RS Cassiop.

	(−1	19)
Dec.	1	6
	7	13
	13	20
	20	3
	26	10

RY Cassiop.

	(−7	10)
Dec.	12	18
	24	21

Approximate Magnitudes of Variable Stars on Oct. 1, 1909.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	h	R. A. 1900. m	Decl. 1900. °	′	Magn.
S. Sculpt.	0	10.3	−32	36	10.2 *i*
X Androm.		10.8	+46	27	11.6*d*
T Androm.		17.2	+26	26	9.2*d*
T Cassiop.		17.8	+55	14	9.5 *i*
R Androm.		18.8	+38	1	6.5 *i*
S Ceti		19.0	− 9	53	9.7 *i*
Y Cephei		31.3	+79	48	9.5
U Cassiop.		40.8	+47	43	9.1
RW Androm.		41.9	+32	8	9.7*d*
V Androm.		44.6	+35	6	11.5*d*
RR Androm.		45.9	+33	50	12.5*d*
RV Cassiop.		47.1	+46	53	<12
W Cassiop.		49.0	+58	1	8.6 *i*
Z Ceti	1	1.6	− 2	1	8.9
U Androm.		9.8	+40	11	<13
S Cassiop.		12.3	+72	5	12.5 *i*
S Piscium		12.4	+ 8	24	<13.5
U Piscium		17.7	+12	21	12.2
R Sculpt.	1	22.4	−33	4	7.3*d*
R Piscium		25.5	+ 2	22	<13
RU Androm.		32.8	+38	10	12.0 *i*
Y Androm.		33.7	+38	50	9.2
X Cassiop.		49.8	+58	46	10.4*d*
U Persei		53.0	+54	20	8.2 *i*
S Arietis		59.3	+12	3	13.3 *i*
R Arietis	2	10.4	+24	35	10.2*d*
W Androm.		11.2	+43	50	8.0*d*
o Ceti		14.3	− 3	26	3.6*d*
R Trianguli		31.0	+33	50	7.8
Y Persei	3	20.9	+43	50	9.0*d*
R Persei		23.7	+35	20	11.9*d*
Nov. Per. 2		24.4	+43	34	12.4*d*
U Eridani		46.2	−25	16	<13
T Eridani		51.0	−24	20	10.0 *i*
W Eridani	4	7.3	−25	24	11.4*d*
R Reticuli		32.5	−63	14	10.4 *i*

Approximate Magnitudes of Variable Stars on Oct. 1, 1909—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A 1900 h	m	Decl. 1900 °	′	Magn.
R Doradus	4	35.6	−62	16	5.2	W Herculis	16	31.7	+37	32	13.4*d*
R Coeli		37.0	−38	26	12.5	R Draconis		32.4	+66	58	10.3*d*
R Pictoris		43.5	−49	26	7.5 *i*	RR Ophiuchi		43.2	−19	17	8.0 *i*
T Leporis	5	0.6	−22	2	9.0 *i*	S Herculis		47.4	+15	7	7.5
— Tauri		43.2	+19	2	<13.5	RS Scorpii		48.4	−44	56	9.8*d*
R Columbae		46.7	−29	13	<13.0	RR Scorpii		50.2	−30	25	7.5 *i*
X Aurigae	6	4.4	+50	15	10.5	RV Herculis		56.8	+31	22	<14.2
V Aurigae		16.5	+47	45	9.8	RT Scorpii		56.8	−36	47	<12.5
R Octantis		56.4	−86	26	11.0*d*	R Ophiuchi	17	2.0	−15	58	7.6 *i*
L^2 Puppis	7	10.5	−44	29	4.5	RT Herculis		6.8	+27	11	10.3 *i*
Z Puppis		28.3	−20	27	12.5	RW Scorpii		8.3	−33	19	13.5*d*
R Carinae	9	29.7	−62	21	5.0*d*	Z Ophiuchi		14.5	+ 1	37	8.0
Y Draconis		31.1	+78	18	13.7*d*	RS Herculis		17.5	+23	1	9.0 *i*
R Urs. Maj.	10	37.6	+69	18	11.6*d*	RU Ophiuchi		28.5	+ 9	30	9.8 *i*
T Urs. Maj.	12	31.8	+60	2	12.3	RW Scorpii		8.3	−33	19	10.8 *i*
RS Urs. Maj.		34.4	+59	2	12.2*d*	RS Ophiuchi		44.8	− 6	40	11.5
S Urs. Maj.		39.6	+61	38	9.5 *i*	RT Ophiuchi		51.8	+11	11	<14
R Hydrae	13	24.2	−27	46	5.0	T Draconis		54.8	+58	14	11.8 *i*
T Urs.Min.		32.6	+73	56	10.0*d*	— Draconis		54.8	+58	13	11.0
T Centauri		36.0	− 3	36	9.0*d*	RY Herculis		55.4	−19	29	12.2 *i*
R Can. Ven.		44.6	+40	2	8.2 *i*	V Draconis		56.3	+54	53	9.9 *i*
R Centauri	14	9.4	−59	27	9.0*d*	R Pavonis	18	3.3	−63	38	9.8*d*
U Urs. Min.		15.1	+67	15	8.6	T Herculis		5.3	+31	0	8.2 *i*
S Bootis		19.5	+54	16	8.3 *i*	W Draconis		5.4	+65	56	10.0
V Bootis		25.7	+39	18	10.0	X Draconis		6.8	+66	8	10.8
R Camelop.		25.1	+84	17	8.1	RY Ophiuchi		11.6	+ 3	40	8.9
R Bootis		32.8	+27	10	8.5 *i*	W Lyrae		11.5	+36	38	8.0
S Lupi		46.8	−46	12	12.5*d*	RV Sagittarii		21.4	−33	23	9.0*d*
U Bootis		49.7	+18	6	11.5*d*	SV Herculis		22.3	+24	58	13.0 *i*
S Serpentis	15	17.0	+14	40	10.0*d*	T Serpentis		23.9	+ 6	14	10.5 *i*
S Coronae		17.3	+31	44	12.5*d*	RZ Herculis		32.7	+25	58	12.5*d*
RS Librae		18.5	−22	33	8.5 *i*	X Ophiuchi		33.6	+ 8	44	9.0*d*
U Librae		36.2	−20	52	13.5*d*	RY Lyrae		41.2	+34	34	10.5 *i*
S Urs.Min.		33.4	+78	58	10.2	RW Lyrae		42.1	+43	32	14.0
R Coronae		44.4	+28	28	11.2 *i*	RX Lyrae		50.4	+32	42	<14
R Serpentis		46.1	+15	26	11.8*d*	S Coron. Aust.		54.4	−37	5	12.8*d*
X Coronae		45.2	+36	35	13.7	ST Sagittarii		55.9	−12	54	<14
V Coronae		46.0	+39	52	12.1*d*	R Coron. Aust.		55.2	−37	6	10.8 *i*
R Librae		47.9	−15	56	13.0*d*	T Coron. Aust.		55.2	−37	6	13.0
RR Librae		50.6	−18	1	11.1*d*	Z Lyrae		56.0	+34	49	13.2
Z Coronae		52.2	+29	32	13.7*d*	RT Lyrae		57.8	+37	22	14.0
RZ Scorpii		58.6	−23	50	11.5*d*	R Aquilae	19	1.6	+ 8	5	7.1*d*
Z Scorpii	16	0.1	−21	28	12.6*d*	V Lyrae		5.2	+29	30	<14.2
R Herculis		1.7	+18	38	13.9*d*	S Lyrae		9.1	+25	50	14.0
RR Herculis		1.5	+50	46	8.3 *i*	RX Sagittarii		8.7	−18	59	13.6
U Serpentis		2.5	+10	12	9.1*d*	RW Sagittarii		8.1	−19	2	9.3 *i*
X Scorpii		2.7	−21	16	11.5	RS Lyrae		9.3	+33	15	9.5 *i*
W Scorpii		5.9	−19	53	11.0 *i*	RU Lyrae		9.1	+41	8	10.5*d*
RX Scorpii		5.9	−24	38	13.0	U Draconis		9.9	+67	7	13.0 *i*
RU Herculis		6.0	+25	20	12.0 *i*	W Aquilae		10.0	− 7	3	10.0*d*
R Scorpii		11.7	−22	42	11.0*d*	T Sagittarii		10.5	−17	9	9.2*d*
S Scorpii		11.7	−22	39	<13.3	R Sagittarii		10.8	−19	29	10.5 *i*
W Coronae		11.8	+38	3	13.0*d*	RY Sagittarii		10.0	−33	42	7.0
W Ophiuchi		16.0	− 7	28	9.5 *i*	S Sagittarii		13.6	−19	12	13.5*d*
V Ophiuchi		21.2	−12	12	8.0	Z Sagittarii		13.8	−21	7	11.0*d*
U Herculis		21.4	+19	7	8.3 *i*	TZ Cygni		13.4	+50	0	10.7
Y Scorpii		23.8	−19	13	12.1*d*	U Lyrae		16.6	+37	42	11.0
SS Herculis		28.0	+ 7	3	12.0*d*	T Sagittae		17.2	+17	28	9.0 *i*
T Ophiuchi		28.0	−15	55	<13	TY Cygni		29.8	+28	6	11.2
S Ophiuchi		28.1	−16	57	<13	RT Aquilae		33.3	+11	30	13.5

Approximate Magnitudes of Variable Stars on Oct. 1, 1909—Con.

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.
R Cygni	19 34.1	+49 58	8.5	V Capric.	20 1.8	−24 19	9.7 *i*
RV Aquilae	35.9	+ 9 42	9.2	TW Cygni	1.8	+29 0	<13
T Pavonis	39.5	−72 1	<13	X Capricorni	2.8	−21 45	14.0
RT Cygni	40.8	+48 32	10.5*d*	RS Aquarii	5.8	− 4 27	12.0*d*
TU Cygni	43.3	+48 49	12.0 *i*	Z Capricorni	5 8	−16 35	10.0*d*
X Aquilae	46.5	+ 4 13	10.0 *i*	R Equulei	8.4	+12 23	11.5*d*
χ Cygni	46.7	+32 40	9.7*d*	T Cephei	8.2	+68 5	7.7*d*
RR Sagittarii	49.7	−29 27	12.8*d*	RR Aquarii	9.8	− 3 19	9.7
RU Sagittarii	51.8	−42 7	11.5 *i*	X Pegasi	16.3	+14 2	12.6*d*
RR Aquilae	52.4	− 2 11	10.9*d*	T Capricorni	16.5	−15 35	11.2*d*
RS Aquilae	53.7	− 8 9	<14	Y Capricorni	28.9	−14 25	13.5
Z Cygni	58.6	+49 46	13.0	S Cephei	36.5	+78 10	8.5
SY Aquilae	20 2.3	+12 39	12.8*d*	RU Cygni	37.3	+53 52	9.2
S Cygni	3.4	+57 42	10.8 *i*	RR Pegasi	40.0	+24 33	13.0 *i*
R Capricorni	5.7	−14 34	12.0 *i*	V Pegasi	21 56.0	+ 5 38	12.4*d*
δ Aquilae	7.0	+15 19	10.9	U Aquarii	57.9	−17 6	13.2*d*
RU Aquilae	8.0	+12 42	9.0 *i*	RT Pegasi	59.8	+34 38	11.0
W Capricorni	8.6	−22 17	13.5*d*	T Pegasi	22 4.0	+12 3	<13.8
Z Aquilae	9.8	− 6 27	<14	Y Pegasi	6.8	+13 52	13.0
RS Cygni	9.8	+38 28	7.4	RS Pegasi	7.4	+14 4	13.6*d*
R Delphini	10.1	+ 8 47	12.5 *i*	R Pisc. Aust.	12.3	−30 6	8.8
RT Capricorni	11.3	−21 38	7.5*d*	X Aquarii	13.2	−21 24	<13
SX Cygni	11.6	+30 46	8.8	RT Aquarii	17.7	−22 34	12.3*d*
RT Sagittarii	11.1	−39 25	8.0*d*	T Gruis	19.9	−38 4	8.5 *i*
WX Cygni	14.8	+37 8	12.2*d*	S Gruis	19.9	−48 57	8.8*d*
U Cygni	16.5	+47 35	7.6*d*	RV Pegasi	21.0	+29 58	12.0
RW Cygni	25.2	+39 39	9.0	S Lacertae	24.6	+39 48	8.0 *i*
RU Capricorni	26.7	−22 2	<13.2	R Lacertae	38.8	+41 51	13.0*d*
Z Delphini	28.1	+17 7	8.0 *i*	S Aquarii	51.8	−20 53	8.4 *i*
ST Cygni	29.9	+54 38	12.8*d*	RW Pegasi	59.2	+14 46	10.2 *i*
Y Delphini	36.9	+11 31	13.8	R Pegasi	23 1.6	+10 0	8.0 *i*
S Delphini	38.5	+16 44	10.6 *i*	V Cassiop.	7.4	+59 8	10.1*d*
V Cygni	38.1	+47 47	13.0	W Pegasi	14.8	+25 44	9.0 *i*
Y Aquarii	39.2	− 5 12	<14	S Pegasi	15.6	+ 8 22	<12
T Delphini	40.7	−16 2	<14	Z Androm.	28.8	+48 16	9.9
V Aquarii	41.8	+ 2 4	9.4*d*	ST Androm.	33.8	+35 13	9.9
W Aquarii	41.2	− 4 27	8.6	R Aquarii	38.6	−15 50	10.0*d*
U Capricorni	42.6	−15 9	13.4	Z Cassiop.	39.7	+56 2	11.3*d*
V Delphini	43.2	+18 58	<14.2	Z Aquarii	47.1	−16 25	9.2
T Aquarii	44.7	− 5 31	9.7*d*	RR Cassiop.	50.7	+53 8	<12.3
RZ Cygni	48.5	+46 59	10.7 *i*	R Phoenicis	51.3	+50 21	8.5*d*
S Indi	49.0	−54 42	10.8 *i*	V Ceti	52.8	− 9 31	12.3*d*
X Delphini	50.3	+17 16	12.5*d*	R Casssiop.	53.3	+50 50	12.2
UX Cygni	50.9	+30 2	<14	Z Pegasi	55.0	+25 21	10.0 *i*
T Octantis	57.4	−82 30	10.8*d*	W Ceti	57.0	−15 14	7.6 *i*
R Vulpeculae	59.9	+23 26	12.8	Y Cassiop.	58.2	+55 7	12.5*d*

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Vassar College Observatory and at the South African and Cambridge stations of the Harvard College Observatories.

GENERAL NOTES.

Meeting of the Astronomical and Astrophysical Society of America, August 19-21. The following notes were received from Secretary Hussey too late to be inserted in the October number of POPULAR ASTRONOMY:

Six general sessions of the society, for the presentation of papers, were held as follows: Thursday morning, afternoon, and evening; Friday morning and evening; Saturday morning.

The society was entertained at a reception given by Professor and Mrs. Frost at their home on Thursday afternoon.

Friday afternoon was devoted to an examination of the equipment and work of the Yerkes Observatory, and later to an excursion around Lake Geneva on private steamers generously furnished by the owners, Messrs. Ryerson, Bartlett, Ayer, and Mitchel.

A motion to change the name of the society to The American Astronomical Society was entertained and lost. It was urged that the present name, by including the words astronomical and astrophysical, gives an equal invitation to astronomers and physicists to participate in its activities.

Upon recommendation of the Council, the society authorized the publication of a decennial volume, to be prepared by a committee to be appointed by the President, and to contain a record of the history and proceedings of the society, together with accounts of the two conferences which preceded the formal organization of the society.

The society adjourned to meet at Cambridge, Massachusetts, in the latter part of August, 1910, the exact date to be fixed by the President and Secretary.

RESOLUTIONS ADOPTED BY THE SOCIETY.

1. "The Astronomical and Astrophysical Society of America assembled in its tenth annual session records its great regret at the death of its first president, Professor Simon Newcomb. Deeply interested in the co-operation and mutual influence of scientific men, Professor Newcomb was conspicuous in the organization and early progress of the society, and was a dominant factor in determining its relation to contemporary astronomy. His enthusiasm for the science and his wide knowledge of its many branches made his presence at and participation in the meetings of the society a perennial inspiration to its members.

Professor Newcomb's own achievements in exact and theoretical astronomy have already become classics in the history of the subject, and will constitute his permanent memorial. The record of a long and active scientific career is closed with the fulfilment of many of his most cherished ideas, and we deeply regret that he was not longer spared for the further development of those subjects to which he had largely contributed.

The society records its profound respect for its departed member and directs its Secretary to transmit a copy of these resolutions to his bereaved family.

2. "As the public through misrepresentation of the views of certain astronomers has formed the impression that communication with other planets is at present possible, the Astronomical and Astrophysical Society of America desires to express its belief that all such proposals fall outside the range of sober contemporary science."

Officers elected :	President,	E. C. Pickering
	First Vice President,	G. C. Comstock
	Second Vice President,	W. W. Campbell
	Treasurer,	C. L. Doolittle
	Councilors for two years,	E. B. Frost
		W. S. Eichelberger
Officers who hold over :	Secretary,	W. J. Hussey
	Councilors,	W. J. Humphreys
		Frank Schlesinger

Fifty-three members were present, as follows :

W. S. Adams
R. G. Aitken
E. E. Barnard
S. B. Barrett
Miss Harriet Bigelow
E. W. Brown
D. Buchanan
W. A. Cogshall
G. C. Comstock
Miss Mary R. Calvert
R. H. Curtiss
W. S. Eichelberger
H. A. Fischer
Mrs W. P. Fleming
A. S. Flint
Philip Fox
E. B. Frost
Miss Caroline E. Furness
William Gaertner
W. A. Hamilton
J. C. Hammond
W. J. Humphreys
W. J. Hussey
William Jewell
F. C. Jordan
Kurt Laves
Miss Henrietta S. Leavitt
O. J. Lee
W. D. MacMillan
J. E. Mellish
D. W. Morehouse
F. R. Moulton
J. A. Parkhurst
W. W. Payne
G. H. Peters
E. C. Pickering
O. L. Petitdidier
Rev. Anton Petrajtis
J. S. Plaskett
John M. Poor
E. D. Roe, Jr.
Frank Schlesinger
Frederick Slocum
H. T. Stetson
C. E. St. John
Joel Stebbins
Ormond Stone
S. D. Thaw
Milton Updegraff
C. E. Van Orstrand
D. T. Wilson
H. C. Wilson
Miss A. S. Young

Forty-one papers were presented as follows :

1. E. C. Pickering. Present needs of astronomy.
2. Joel Stebbins. Some results with a selenium photometer.
3. Miss Henrietta S. Leavitt. Standard photographic magnitudes.
4. J. C. Hammond. Graduation errors of the circles of the circles of the six-inch transit circle of the Naval Observatory.
5. R. S. Dugan. The Algol system Z Draconis.
6. K. Laves. Determination of the Moon's theoretical spectroscopic velocity.
7. K. Laves. The problem of three bodies from the standpoint of spectroscopy.
8. W. J. Hussey. Improvements in the Observatory at Ann Arbor.
9. E. W. Brown. New plans for tabulating the Moon's longitude.
10. E. E. Barnard. On the proper motion of some of the small stars in the dense cluster M 92 Herculis.
11. F. R. Moulton. Some considerations on globular star clusters.
12. W. J. Humphreys. A proposed method of studying solar radiation at great altitudes.
13. E. D. Roe, Jr. Achromatic and apochromatic comparative tests.

14. W.W. Campbell. Report of progress on the radial velocity program of the Lick Observatory.
15. R. G. Aitken. Report of progress in the Lick Observatory double star survey.
16. H. D. Curtiss. Thirteen stars having variable radial velocities.
17. H. D. Curtiss. Three stars of great radial velocity.
18. H. D. Curtiss. Spectroscopic and photographic observations of comet *c* 1908 (Morehouse).
19. S. Albrecht. Note on the apparent wave lengths of the lines in the different spectral types and in certain variable stars.
20. J. A. Parkhurst. Precautions necessary in photographic photometry.
21. J. S. Plaskett. The effect of faulty collimation of the correcting lens on the star image.
22. E. E. Barnard. On the photographs of comet *c* 1908 (Morehouse).
23. R. M. Motherwell. The photographic doublet of the Dominion Observatory.
24. E. C. Pickering. The unpublished work of the Harvard Observatory.
25. W. H. Pickering. The photographic search for planet *O*.
26. Philip Fox. The use of quartz fibers for micrometer wires.
27. W. J. Humphreys. Planetary magnetism of the Sun.
28. E. B. Frost. Lack of spectroscopic evidence of a dispersion of light in space.
29. J. S. Plaskett. The width of slit giving maximum accuracy.
30. Mrs. W. P. Fleming. A photographic spectrum of a meteor.
31. R. H. Curtiss. On differential flexure in the single prism spectrograph of the Detroit Observatory.
32. Miss A. J. Cannon. A new variable star of the class R Coronae.
33. W. J. Humphreys. Vertical temperature gradients in the atmosphere, as determined by season and by types of weather.
34. Frank Schlesinger. A proposed design for an objective prism spectrograph for the determination of radial velocities.
35. Philip Fox. Solar spectroscopic observations.
36. R. H. Curtiss. The new spectroscopic measuring engine of the Detroit Observatory.
37. R. H. Curtiss. The focal curves of the single material camera doublet of the single prism spectrograph of the Detroit Observatory.
38. F. B. Littell. The pivots of the nine-inch transit circle of the U. S. Naval Observatory.
39. Edgar Tillyer. On the clock vault of the U. S. Naval Observatory.
40. G. H. Peters. On the construction of astronomical photographic objectives at the U. S. Naval Observatory.
41. E. E. Barnard. On some experiments in photographing enlarged images of the planets direct with the forty-inch telescope.

1. Report of the Committee on Comets. G. C. Comstock, Chairman.
2. Report of the Committee on Luminous Meteors. Cleveland Abbe, Chairman.

Halley's Comet. We are fortunate in living in Elgin, Ill., for a little while, because we are so near Yerkes Observatory, that interesting place where so much important astronomical work of the original kind is going on constantly.

We knew that E. E. Barnard has been very busy since the first detection of the return of Halley's comet in getting photographs of it on almost every

possible occasion. So a few days ago we sought an opportunity to see what success he had with his powerful instruments in getting a photograph of the comet when its faintness is rated as about that of a sixteenth magnitude star. We were delighted with the results which we saw. The head of the comet was very plainly seen. It was round quite like a faint star. There was in our eye no central condensation. That could hardly be expected in so faint an object.

At first thought, it came to us how do we know we are certainly seeing the famous Halley comet? It looks too much like stars in the neighborhood. Possibly these good people are mistaken. We then examined two plates in the comparator, which is an instrument that works on the principle of a dissolving projection; by the shift of a diaphragm one can be seen, and then the other almost instantly in the same field of view. Two plates, showing the same field, one taken before the comet was visible and the other after were so exhibited. This was a very satisfactory answer, and helped us to appreciate the ease and certainty with which the identification of faint objects can be made by the aid of the comparator.

From all that we saw at the observatory we are led to believe that the observers there will have, in many different ways, as full an account of this return of Halley's comet as it will be possible for them to get in the opportunities that the weather will afford. They certainly do not lack in instrumental equipment for its study, nor in interest or enthusiasm to work them at full capacity.

A Word of Encouragement for Amateurs with a Small Telescope. Having accomplished so much on Mars with my 3½-inch refracting telescope, I thought possibly some one interested in amateur astronomy, and possibly not possessing a telescope as yet, might be encouraged to make an effort before Mars is too far distant for good viewing. When I purchased my telescope a few months ago, I was told by a leading authority that I could hardly expect to see either the polar cap or the markings. I have seen both very distinctly, though the polar cap is a rather difficult object to catch now having become so small.

The large dark areas visible in such a telescope have been quite clear at times of good seeing and I have detected the green hues several times. I have also seen the shapes quite clearly. About the time of opposition, I noted that the shaded area was large and round, or oval, in the evening hours while it was narrow and long the next morning,—passing across the entire surface of the planet, as it appeared. Last night's observation appeared more as it looked during the morning hours in September.

I have found that eyepieces with powers 45, 65, 90, 110 and 200 are best suited for the use of such a telescope. The 90 is most used and the 200 only rarely at times of good seeing on Saturn and the Moon. I have been able to use the 200 but once or twice on Mars. When properly lighted and when some of the finest and largest craters of the Moon are on the terminator the 200 shows up grandly the walls, the shadows and inner hills.

I found that one of the finest times for observing Mars was to be obtained in the early morning just as it was beginning to get light,—the glaring light of Mars thus being screened in part. As Mars sets too early for this now, I see no reason why the early evening should not produce the same result.

I am looking every few days for Halley's comet, and would enjoy being the first amateur to find it. R. W. ROBERTS.

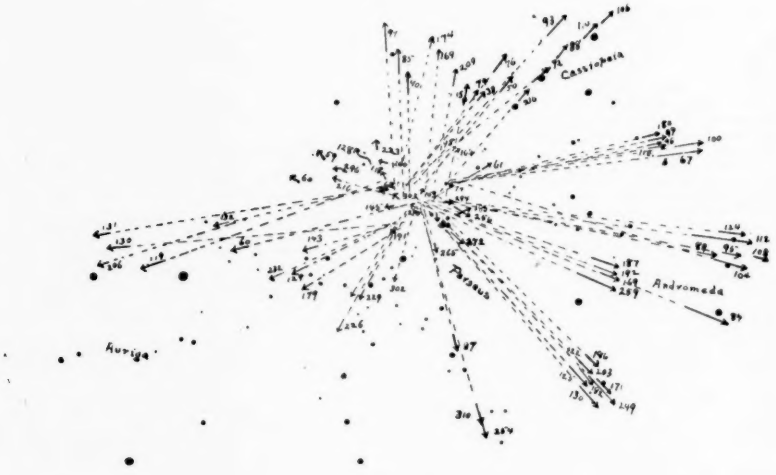
Edgerton, Wis., Oct. 8, 1909.

Observations of Perseids 1909. August 9 and 10 were unfavorable, but the 11th was a perfect night. Three were seen the 9th, 33 the 10th and 302 the 11th with 65 from other radiants. For the most part they were faint this year, although several were as bright as Mars, especially No. 255 which passed directly below Mars so that it could be compared. There were several near the radiant point, appearing like dots, head on. Following is a tabulation.

Aug. 9			3
Aug. 10			33
Aug. 11	7:30- 9	P. M.	17
	9 -10		13
	10 -10:30		15
	10:30-11:00		14
	11:00-11:30		21
	11:30-12:00		23
	12:00-12:30	A. M.	24
	12:30- 1:00		24
	1:00- 1:30		30
	1:30- 2:00		29
	2:00- 2:30		20
	2:30- 3:00		34
	3:00- 3.32		38

By magnitudes of 282 observed.

−3	Mars	−1	0	1	2	3	4	5	6
1	2	3	26	43	45	44	39	29	54



PERSEIDS.
August 11, 12, 1909
Belmont, Mass.

Of 282 only 67 showed trails, and 21 were so near the radiant as to hardly move. About 114 were mapped.

	Trail		Trail		Trail
7	3 B—6w	95	1w, 4w	182	6w
8	2w—5w	96	6w	185	6w
9	3B—6w	99	6w	186	6w
16	2w—4w	100	4w	187	6w
18	2w—5w	102	0w—2w	191	3w
24	4w	103	3w	200	4B
31	2w—5w	104	3w	203	2w
34	4w	105	3w 5w	204	6w
47	4w—6w	106	2w	206	1w
50	4w	108	6w	209	5w
59	0w—5w	111	3w 5w	214	6w
60	2w—5w	112	0w 4w	216	2w
61	3w—5w	115	4w	223	2w
62	3w—5w	116	6w	225	6w
67	2w	118	3w	226	6w
69	2w	119	0R 3w	228	3w 5w
70	3w	122	2w	229	2w 4w
71	3w	124	3w	232	1w 5w
72	3w	125	6w	238	1w
73	4B	128	4 curved	249	2w
74	2w 5w	129	0w 3w	254	1w 5w
75	6w	130	0w 3w	259	2w
76	5w	131	0w 5w	265	3 4w
78	5w	132	3w	270	4w 4w
81	5w	138	3w	272	4w
82	1w 5w	140	1w 4w	286	6w
83	6w	143	1w	291	4w
84	1w 6w	145	4w	294	1w
85	1w 5w	147	0w	295	4w
86	1w 5w	162	3w	296	5w
87	3w	167	5w	301	4w
88	6w	168	3w	302	4w
89	6w	169	1R 4w	303	0w 4w
90	6w	171	2w 5w	310	2w 4w
91	6w	174	1R		
92	6w	179	2w 5w	196	3w
93	4w	180	4w		

The Perseids in the N. W. near Ursa Major were bright, near the radiant usually very faint, in the south or through Lyra large with fine trails. August 12th was entirely cloudy.

ROBERT M. DOLE.

Observed at Belmont, Mass.

Rietz and Crathorne's College Algebra. A new text-book in college Algebra by Rietz and Crathorne came to our library recently. It is designed for use in the first year in colleges and technical schools. An examination of the contents of the book shows that it is very well adapted to that grade of work. The first pages of the book give in a clear and condensed form the elementary topics, so that the student may quickly recall the things he learned a few years previously and has partly forgotten. The graph, and the functional notation and the solution of equations by determinants are introduced early. The student is thus familiar with these concepts when he comes to use them in the more advanced topics. The book contains an abundance of material and will doubtless be found to be entirely satisfactory as a text for Freshman mathematics.

A Journey to the North Pole? The following fictitious observations of the Sun will indicate the positions along Dr. Cook's route to the pole as published by the press. Their reduction may serve as interesting exercises for classes in practical astronomy.

Observations marked with an asterisk are for determining local mean time, and hence longitude. The others are noon or midnight observations for latitude. The chronometer is supposed to keep G. M. T., fast $10^m\ 14^s$ on Mar. 20 and gaining 2^s daily.

Date 1909	⊙ Double Alt. Lower Limb.	Chron. G. M. T.	Index + Eccentr.	Temp. F.	Barom.	Dead Reck. Lat.
	° ′	h m s	′			° ′
Mar. 20	15 6.6	6 31	−2.2	−42	29.7	
	* 6 24.0	11 3 50	2.0	44	29.8	82 23
26	15 39.2	6 42	2.2	40	29.7	
	* 8 34.1	11 22 18	2.1	42	29.6	84 24
29	17 12.3	6 35	2.3	38	29.8	
	*10 8.5	11 27 0	2.5	40	30.0	84 50
Apr. 7	20 35.9	6 30	2.7	40	29.6	
	*15 38.4	11 9 45	2.8	42	29.7	86 36
11	21 56.8	6 33	2.8	36	29.8	
	*17 40.0	11 34 35	2.6	40	29.8	87 20
14	21 54.6	6 34	3.0	37	29.6	
	16 16.1	18 30	2.7	39	29.7	
19	23 7.2	6 30	2.8	38	29.8	
	21 58.3	18 32	2.5	41	29.6	
20	23 18.2	6 25	2.7	40	29.5	
	23 6.5	18 28	2.7	42	29.7	
21	23 31.4	6 30	3.0	40	29.7	
	23 51.2	18 35	−2.8	−38	29.8	

University of Nebraska. W. W. BRENKE.

Solar Magnetic Fields. It is extremely gratifying to believe that some progress is being made in the study of the surface of the Sun in recent months on Mt. Wilson at the Solar Observatory under the leadership of its director, Professor George E. Hale.

The recent forward steps of progress which have been taken are reported tentatively and mainly in provisional form. That it is so, we do not wonder because of the extreme difficulty of getting enough clear data separated from all other conditions of uncertainty and similarity to support well the contention for any new and important step of pending solar problems.

But Professor Hale cautiously presents some things in recent months that from their novelty and their reasonableness at once get the attention of all interested in the study of the Sun. These suggestions point to a peculiar vortical structure often apparent in portions of the solar surface as seen on the spectroheliograms obtained at Mt. Wilson, which suggests an analogy to things taking place in our terrestrial atmosphere. He notes also that there are important differences between the atmospheres of the two bodies. For example, he says, the temperature of the solar vapors appear to be practically uniform from the equator to the poles, and that this fact seems to explain why the existence of convection currents have not been recognized in any considerable degree on the solar surface in the direction of its latitude. Of course, we suppose this suggestion does not at all disturb the view that is generally held about the shift of the solar surface in latitude, in the equatorial regions which is somehow related to the eleven year sun-spot period.

The evidence that the photographs, or the lack of it, is the fact that they do not show any stream lines which should be expected if it were true that convection currents flow from the equator of the Sun to its poles.

It has been known for a long time that a whirling motion exists in the sun-spot areas. In many instances this fact has been noticed by observers who use the spectroscope, but it has been quite impossible to form any satisfactory theory as to the cause of the sun-spot from this interesting fact. The mysterious cause by it seemed further removed than ever.

The new thing which Professor Hale suggests is that from a great mass of information collected, it appears that there is a similar effect presented from light sources in the physical laboratory when subjected to the magnetic field. If true that means that there is an interaction of these magnetic fields of the solar atmosphere on our terrestrial atmosphere and that such action is related to terrestrial magnetic storms. Mr. Hale does not say that solar magnetic conditions are the cause of terrestrial magnetic storms, for investigation has not yet gone far enough to formulate a theory to relate cause and effect, but it is true that these suggestions and tentative steps taken in guarded and scientific way are justly giving to the solar work on Mt. Wilson a prominence in scientific circles that it well deserves.

Auchincloss' Chronology of the Bible. There has just come to hand a copy of Auchincloss' Chronology of the Bible, a work, the preparation of which has been going on for years past, and the completion of which has been waited for with keen interest and most hopeful expectation.

This new book is a volume of ninety-eight pages, very neatly printed and bound in cloth and is the work of the D. Van Nostrand Company of publishers of New York City. It bears on its title page the date 1909.

On opening the new volume, almost the first thing the eye catches is the name of Dr. A. H. Sayce, the noted Assyriologist and professor of Queen's College, Oxford, England. That name for the modern student in Bible study is almost a household word.

Of course one wants to know what that great scholar, that profound thinker, fresh from the field of ancient record, old and new, has to say about a new book on Bible Chronology, one of the most difficult pieces of work to do in all the range of modern scholarly activity. The interested Bible student will be delighted to see that the introduction to this new book is written by Dr. Sayce, for which few persons in the world, if any, could have been better chosen. He will have the greatest satisfaction to read from this introduction to the book such an important view of its real merit as is set forth in words of his own from the first paragraph. He says :—

"Light has been thrown upon the chronology of the Old Testament by recent discoveries in Egypt and Assyria, but the application of these discoveries must be preceded by a thorough examination of what the Old Testament itself has to tell us upon the subject. Older chronological schemes like those of Usher or Hales have long since been discredited, and the time has come for a scheme that will better suit the requirements of to-day. Such a scheme is presented by Mr. Auchincloss, whose book contains an exhaustive account of the chronological data of the Old Testament. The student will find not only all the material needed by the chronologist, but also a combination of them into a consistent and scientifically checked system. No pains have been spared to make the work at once complete and clear, and the tables have been supple-

mented by a chronological index which will much facilitate their use."

The seven parts of this book deal respectively, with the data assembled and analyzed are; Josephus and Chronology, the Bible Chronology, Israel and Chronology, Assyria and Chronology, Bible dates and the Julian calendar and a chronological index.

As one glances through the pages of this new book, and gets knowledge of the scheme, he finds it entirely new and original, and he is not a little surprised to find that its authority rests wholly on the numerical statements of the Bible itself, regardless of other sources of information, the very feature in some other chronologies which has caused harmful confusion and error in their schemes.

The scientific character of this work will appeal to scholars in all the related sciences because the work is done in a scientific way. The beauty of the Bible record with all its historical data is greatly varied in its character, and this is brought out by the author's system of checks and counter checks of its numerical statements, showing in a remarkable way the original sense and integrity of the Bible text amidst the possible errors of translators and copyists through all the past time of fifty-three eventful centuries.

This book gives the Bible student the needed help in chronology that will be appreciated the world over.

Mars Photographed at Yerkes Observatory. Another of the objects in mind in visiting Yerkes Observatory recently was to know what success E. E. Barnard had in photographing the planet Mars in this opposition.

In the study of these plates we were greatly interested, because the same kind of work done elsewhere has been published or particularly described and it was our desire to see how the results compared.

We saw a mass of detail in the Barnard plates the same appearing in plate after plate as they were carefully compared. The images were enlarged several times so that they were about three-fourths of an inch in diameter, and the surface would show pretty well in that size. We looked intently for the definite markings called canals, and we could see many faint shadowy markings on the surface of the planet, that looked quite prominent, but not well defined or easily traced to any considerable distance. Beyond these markings there were many more that were within the reach of the eye, but they were even less well defined, and beyond the power of sketching, as would seem, from the little study given them, because of their great number.

We do not write this to pronounce on what is, or what is not, the extent or the kind or the character of the markings on the surface of the planet Mars. We are not an expert student or an expert observer of the surface markings of that interesting planet. Therefore not in any sense, an authority in this matter, but only a casual observer. Our present impression is that the surface of Mars contains abundantly more detail of markings than we had ever dreamed of before. We think photography will soon do more for us.

It is yet too soon to report what has been seen by astronomers generally, for though the best time for study on account of distance from the Earth is past, yet many are doubtless following the ruddy planet still, and will continue to do so as long as favorable seeing lasts.

Erratum. Director W. W. Campbell calls our attention to an error in the Harvard College Circular, as printed on page 523, October POPULAR ASTRONOMY, concerning his observations of the spectrum of Mars on the summit of Mt. Whitney, saying that the conclusions should have read: "Little 'a' water vapor bands estimated equal intensities (in Martian and lunar spectra) and very faint."

An error crept into the telegram after it left San Jose, California. A detailed account of the observations, in press, will be issued soon as a Lick Observatory Bulletin.